PECULIARITIES OF MICROWAVE RADIO BURSTS AND CORONAL ACTIVITY FROM THE SOLAR FLARES PRECEDING TO THE LARGE FORBUSH DECREASE

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Abstract

From the observational data NM Lomnicki Stit during 1997-2006 we analyzed the Forbush Decrease (FD) events with large amplitudes (>4-6%). For these events the features of solar flares at optical and radio ranges were studied.
As the rules, the flares preceding to the large FD were characterized by the power microwave bursts (f=15.5 GHz) with fluxes increased to 10^2 -10^3 times. Usually during these flares were observed radio bursts of II,III types, CME with large velocities, disturbances at solar wind and geomagnetic storms with Dst < -100 nT (if Bz<0 exists) and with delay about 2 days.
The relations between FD and microwave bursts may be explained by the large amount of plasma and accelerated particles, ejected during the flares with power microwave and hard X-ray (HXR) bursts.

Introduction

The study of the solar flares at various energetic ranges during the period preceding to the large Forbush Decreases (FD) is very important from the practical point of view, when we analyze the Space weather [1] and also for theoretical research. It is known, that after the flares we observed the disturbances in the interplanetary medium, at the solar wind, in the structure of magnetic field during the propagation of coronal mass ejections (CME), magnetic clouds and shock waves. The increase of the density at the space near the Sun, caused by the ejections of the plasma during the flare, is the important condition for decrease the flux of the galactic cosmic rays, registered at the Earth (Forbush Effect). From the data of Pioneer-10, 11 and Voyager -1,2 satellites are FD observing to orbit of Neptune.

At the various publications are analyzed the connection of FD with geomagnetic storms [2], the parameters of solar wind [3,4] and with features of CME [5-8].

About the plasma, ejected during the flares, we may judge from the observations of CME, magnetic clouds (MC) and radio bursts of II and IV types, which characterized the spread of shock wave and the plasmoid through the solar corona.

As the significant parameter, determined the plasma ejection, we may consider the flux of microwave radio emission F_{max} and hard X-ray $F_{x,}$ because its caused by the processes of the acceleration and energy exit at the flare [9]. According to the statistical analysis, 60-84% of the events with CME-halo type and velocity V_{cme}>1000 km/s are connected with microwave bursts at frequency range f=2 -20 GHz and the flux F_{max}>1000 units [10].

The comparison of the radio bursts of VLA, Nancay (150 -450 MHz), Nobeyama (17 GHz) with CME (SOHO) also give the basis to the study of the connection microwave emission and the ejection of plasma during the flare.

The analysis of the observational data

With the purpose of the investigation of the flares with large fluxes of microwave emission and their comparison with the periods of FD, we select the events of the solar flares with the radio bursts at frequency f=15.4 GHz and the flux F_{max}>1000 units (10^{22}W/m^2.Hz) during the period 1997-2006. These data we compared with the observations at the Neutron Monitors (NM). The list of the events, registered at the various stations, we may find at the sites of Lomnicky Stit [11], NIZMIRAN, Moscow [12], Oulu [13]. Several events from these data, the more important, are given at the Table 1.

This Table contents the dates of FD observation and decreases of intensity at %. For these periods are given the chromospheric flares (date, Importance, coordinates , number of Active Region), the flux of radio emission (F_{max}) at f=15,4 GHz, the bursts of II,IV types of metric and hectometric ranges [14,15] and velocities of CME from the Catalogue of SOHO [16,17]. Besides are included the Dst, determined the geomagnetic storms during the period of FD [18]. For the some events we have considered the solar fluxes of hard X-ray (HXR) Fx at the rather energy range E from the data of RHESSI [19]. At last, we marked the events with GLE (Ground Level Enhancement), registered at Lomnicky Stit and discussed at [20] and gamma-ray (g) from Yohkoh [22].

From the analysis of the Table 1 it follows that the flares, preceding to the large FD were usually of X and M Importance, developed at the sunspot groups with complex magnetic fields and localized at the geo-effective longitudes. The flares are accompanied by the radio bursts of II, IV types, CME with the large velocities and the geomagnetic storms with Dst < -100 nT. At these flares the flux of microwave exceed the value F_{max}=1000 units. In the events with large Forbush Decreases the fluxes at frequency 15.4 GHz increased to the two orders.

As the example, we select the events at the next periods: X-XI, 2003, VII.2000, I 2005, XI 2004, XII 2006, when the FD were more, than 10-20%. At all these cases the flux of microwave bursts achieved the extreme values F=10^4 -10^5 units. (see the Table 1). It is noticed, that the most of the events with FD 3-4%, as a rule, corresponded to F_{max} > 1000 units.

At the Figures 1-4 are given the temporal profiles of FD for the several important events, registered at the Lomnicky Stit [11].

Besides of the microwave emission from the solar flares, for the comparison with FD the HXR bursts are of especial interest, if we may judge from the observational data of RHESSI [19]. The data for several events are given at the Table 1. It is known, that HXR during the power flares increased to a great extent, similar to the microwave bursts, and characterized the acceleration and plasma motion.From the data of Table 1 we conclude, that to the events of FD preceded the flares with large HXR bursts and the fluxes Fx=10^6 units at range E=50-100 keV.

As concerned to the geomagnetic disturbances during the most of events, given at the Table 1, geomagnetic storms with Dst < -100 nT were observed (with the condition for solar wind Bz<0). The onset of geomagnetic storms, as usually, observed with delay aproximately during the two days relatively to the explosive phase of the flare. It is noticed, that exist the problems at the study of the connection FD and geomagnetic storms [1] and may be it is possible to consider in details the various features of solar wind, CME, shock wave and interplanetary disturbances, MC and corotating interaction regions as a complex for every special period of FD, and in addition to take into account also the peculiarities of microwave and HXR bursts from the flares.

Conclusion

At the flares, preceding to the large Forbush effect with the decreases more 3-10 % are observed the fluxes of microwave radio bursts at the f=15.4 GHz with amplitudes $F_{max}=10^3-10^4$ units.

We suppose, that microwave radio and hard X-ray emission, caused by the plasma ejection and the acceleration of energetic particles during the flares, together with CME and MC, may be the precursor of Forbush Decreases appearance and determined its physical features.

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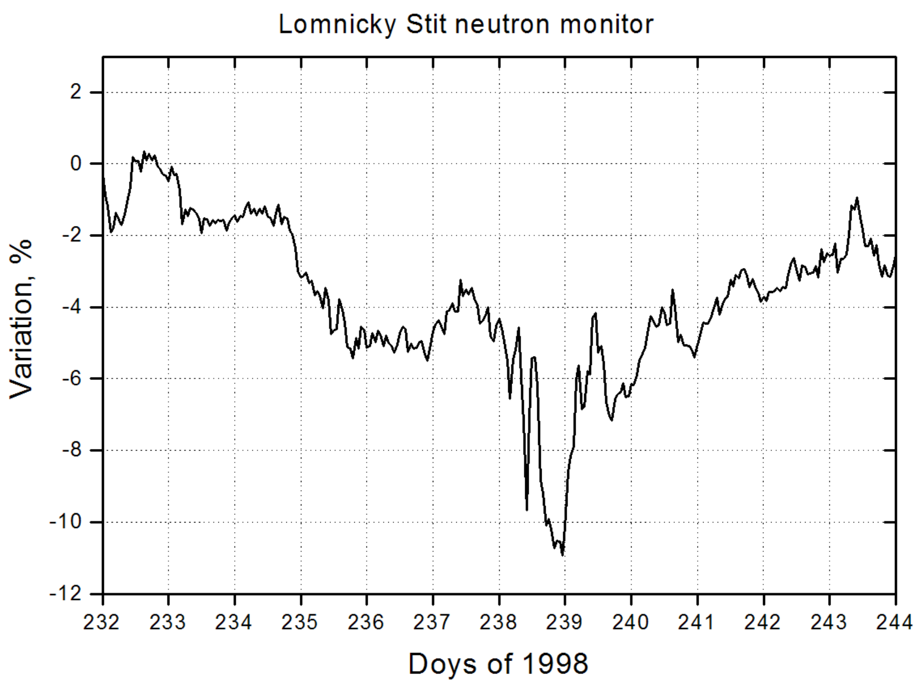

Figure 1. The Forbush decrease, measured on August 26, 1998 by Lomnicky Stit neutron monitor.

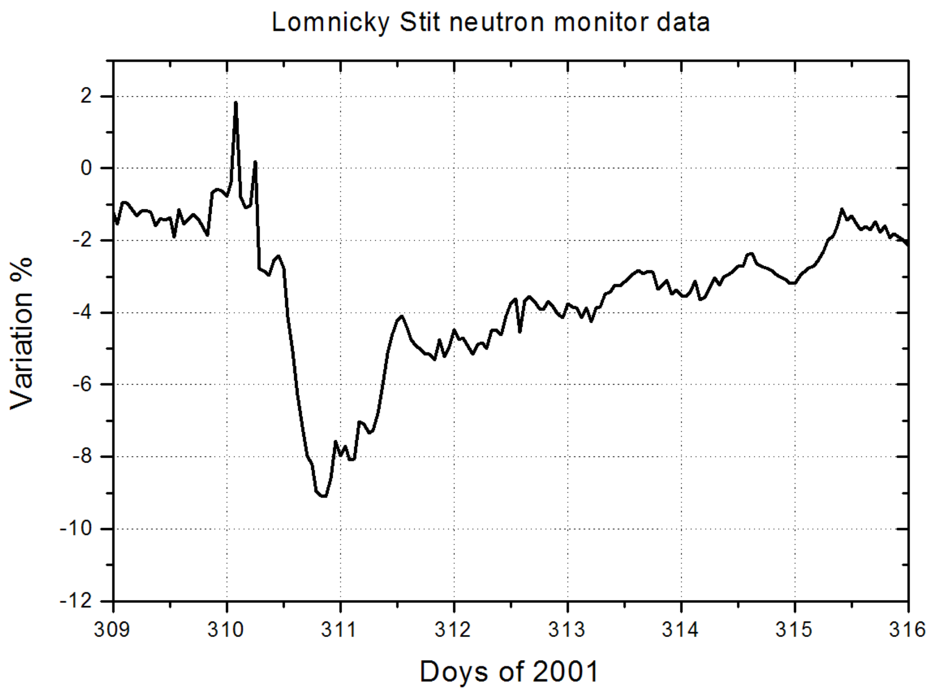

Figure 2. The Forbush decrease, measured on November 6, 2001 by Lomnicky Stit neutron monitor.

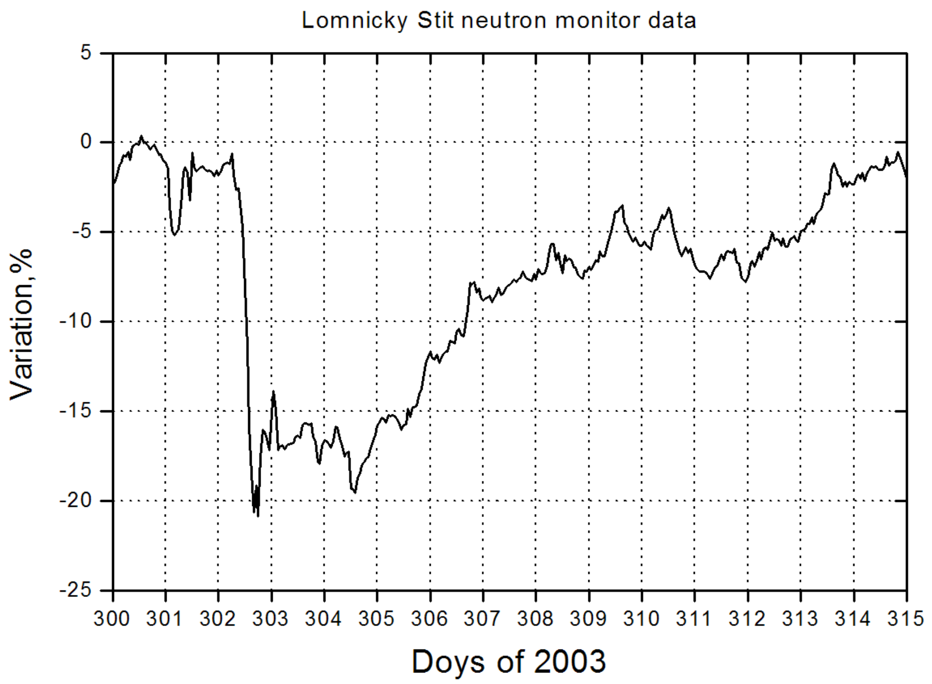

Figure 3. The Forbush decreases, measured on October 29, 2003 by Lomnicky Stit neutron monitor.

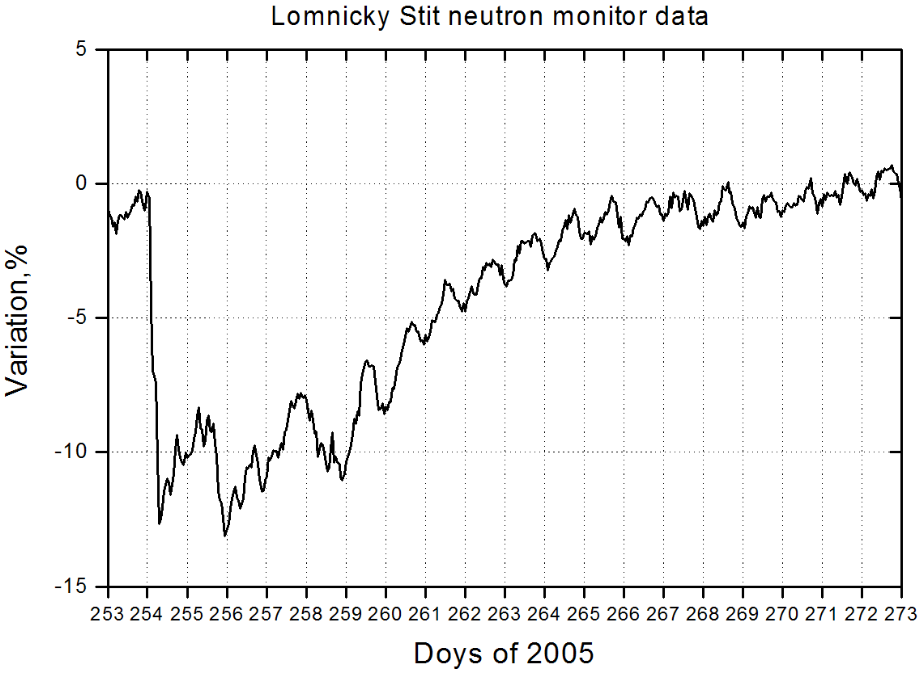

Figure 4. The Forbush decreases, measured on September 11, 2005 by Lomnicky Stit neutron monitor.

Table 1. List of solar flares, radio emissions, velocities of CME and HXR fluxes during large FD periods.

Forbush decrease Data	Int FD [%]	Solar Flare Data	Import. Xray/Opt	Coord.	UT_{max}	F_{max} 15.4 GHz	gamma /GLE	Act.Reg.	V_{cme} [km/s]	Dst [nT]	HXR Fx	HXR E [keV]
06.11.1997	3%	04.11.	X2.1/2B	33W	05.57	1600		8100	785			
		06.11.	X9.4/2B	63W	11.57	9800	g/GLE		1556	-110 (06.11.)		
02.05.1998	4.4%	02.05.	X1.1/3B	15W	13.41	1300		8210	938			
06.05.1998	9%	06.05.	X2.7/1N	65W	08.07	1500		8210	1099	-192 (04.05.)		
18.08.1998	6.5%	18.08.	X2.8/1N	68E	08.21	4100	g					
		18.08.	X4.9/1B	87E	22.16	6900		8307	1830			
		19.08.	M3.0/SF	80E	14.12	1100		8307				
		19.08	X3.9	75E	00.03	5800		8307				
22.08.1998	6.5%	21.08.	?	-	-	1400		8307				
		23.08.	M2.2/1N	33E	09.31	1200		8307				
26.08.1998	12%	24.08.	X1/3B	07E	22.03	1000		8307		-155 (26.08.)		
25.09.1998	9%	23.09.	M7.1/3B	09E	06.56	1000		8340		-207 (25.09.)		
08.11.1998	7%	05.11.	M8.4/2B	18W	19.44	520		8375	1118	-149 (08.11.)		
		06.11.	M1.7/1B	32W	15.10	<400		8375				
25.11.1998	2%	22.11.	X3.7/1N	82W	06.39	8700	g	8384				
		22.11.	X2.5/2N	89W	16.20	1400		8384				
		24.11.	X1.0	?	02.15	1400						
14.12.1998	4%	18.12.	M8.0/2N	64E	17.18	1200			1749 (18.12)			
20.08.1999	4.7%	20.08.	M9.8/1N	64E	23.06	2100		8674				
22.08.1999	3.6%	21.08.	M3.7/1B	58E	16.33	560		8674				
08.06.2000	6%	06.06.	X2.3/3B	18E	15.19	1600		9026	1119			
10.07.2000	3.5%	10.07.	M5.7/2B	49E	20.12	2600		9077	1108			
13.07.2000	7.5%	12.07.	X1.9/2B	49E	22.10	1600		9077				
15.07.2000	7.5%	14.07.	X5.7/3B	07W	10.31	5500	g	9077	1624			
16.07.2000	8.5%	17.07.	M2.4/1N	36E	20.24	2200		9087				
		25.07.	M8.0/2B	08W	02.48	2800	g	9097	528			
17.09.2000	7 %	16.09.	M5.9/2B	07W	04.13	1200		9165	1215	-201(17.09.)		
27.11.2000	5.1%	24.11.	X2.0/3B	05W	05.00	5500		9236				
		24.11.	X2.3/2B	05W	15.08	14000	g	9236	1245			
		25.11.	M8.2/2N	50E	01.22	1700	g	9240				
		25.11.	X1.9/2B	23W	18.30	4600	g	9236				
29.11.2000	4.9%	26.11.	X4.0/2B	38W	16.43	3900	g	9236	980	-119(29.11.)		
28.03.2001	5%	27.03.	M2.2/1N	33E	16.29	1300		9401				
31.03.2001	4.5%	29.03.	X1.7/1F .	12W	10.11	4000		9393	942	-387(31.03)		
04.04.2001	6%	02.04.	X1.4/1B	60W	10.07	1200		9393				
		02.04.	X20	60W	21.49	14000	g	9393	2505			
		03.04.	X1.2/1N	83E	03.29	6300		9415	1613			
		05.04.	M8.4	35E	09.17	1700		9415	1705			
		05.04.	M5.1/2N	50E	17.08	4600		9415				
08.04.2001	5%	06.04.	X5.6/1F	31E	19.18	6700	g	9415	1220			
12.04.2001	9.5%	09.04.	M7.9/2B	04W	15.26	5900		9415	1192			
		10.04.	X2.3/3B	09W	05.23	5000		9415	2411			
13.04.2001	6.9%	11.04.	M2.3/1F	27W	13.17	1200		9415	1103	-271(11.04.)		
		12.04.	X2.0 /SF	43W	10.17	6200		9415	1184	-236(12.04.)		
		15.04.	X14/2B	85W	13.49	5100	g/GLE	9415	1199	-114(18.04.)		
28.04.2001	5.5%	25.04.	M2.7 /2N	09W	13.47	520		9433	1006	-47 (29.04.)		
28.08.2001	4.7%	25.08.	X5.3/3B	34W	16.32	41000		9591	1433	-40 (31.08.)		
26.09.2001	6.8%	24.09.	X2.6/2B	23E	10.29	15000		9632	2402			
21.10.2001	5%	19.10.	X1.6/2B	18W	16.24	4200		9661	901			
		22.10.	X1.2/2B	16E	17.51	3700		9672				
06.11.2001	10%	04.11.	X1.0/3B	18W	16.17	1600		9684	1810	-292(06.11.)		
24.11.2001	9%	22.11.	M9.9/2N	34W	23.30			9704	1443	-221(24.11.)		
30.12.2001	7%	26.12.	M7.1/1B	54W	05.07	1800	GLE	9742	1446			
		28.12.	X3.4	52E	20.17	1400		9767	2216	-58(04.11.)		
17.07.2002	4%	15.07.	X3.0/3B	01W	00.08	20000		10030	1300		$0.50.10^{6}$	50-100
25.07.2002	2.5%	20.07.	X3.3	75E	21.26	43000	g	10039	1942		$1.58.10^{8}$	50-100
		23.07.	X4.8/2B	72E	00.31	10000	g	10039	2285		$2.36. 10^{6}$	300-800
27.08.2002	2.5%	24.08.	X3.1/1F	81W	01.12	17000		10069	1913		$5.00. 10^{6}$	50-100
29.05.2003	6%	28.05.	X3.6	17W	00.23	5300		10365	1366			
		27.05.	X1.3/2B	17W	23.06	1200	g	10365	964			
		29.05.	X1.2/2B	13W	19.34	2100		10365	1237		$8.50. 10^{6}$	25-50
		31.05.	M9.3/2B	65W	02.22	8300		10365	1835	-130(29.05.)	$11.80. 10^{6}$	25-50
24.10.2003	4%	23.10.	X5.4/1B	88E	08.27	10000		10486			$13.00. 10^{6}$	12-25
		24.10.	M7.6/1N	72E	02.24	5100		10486			$10.00. 10^{6}$	100-300
		25.10.	M1.5/SF	20W	10.29	3800		10484				
		26.10.	M7.6/2N	38W	21.38	1200		10484				
28.10.2003	3.5%	26.10.	X1.2/SF	44E	07.29	6900		10483				
		26.10.	X1.2/1N	38W	17.30	3100		10484	1537			
		27.10.	M5.0/1F	26E	09.23	3900		10486				
29.10.2003	22%	28.10.	X17/4B	38E	01.0	57000	g/GLE	10486	2459		$2.40. 10^{8}$	12-25
		29.10.	X10.0/2B	02W	20.47	(11000					$0.40. 10^{9}$	3-6
						-8.8GHz)	g/GLE	10486	2029	-401(30.10.)	$0.90. 10^{6}$	100-300
04.11.2003	4%	02.11.	X8.3/2B	58W	17.16	30000	g/GLE	10486	2598		$0.65. 10^{9}$	300-800
		03.11.	X3.9/SF	77W	10.06	17000	g/GLE	10486	1420		$4.80. 10^{6}$	100-300
		03.11.	M3.9/SF	79W	15.28	1400		10486			$2.70. 10^{6}$	12-25
		04.11.	X28/3B	83W	19.45	60000		10486	2657	-89(04.11.)	$3.80. 10^{6}$	50-100
22.07.2004	4.5%	16.07.	X3.6/3B	35E	13.52	5600		10649			$8.30. 10^{6}$	100-300
											$3.30. 10^{6}$	25-50
		20.07.	M8.6/3B	34 E	12.30	7500		10652			$8.60. 10^{6}$	25-50
26.07.2004	10%	24.07.	C4.8/SF	11W	13.34	1600		10652			$3.80. 10^{6}$	50-100
		25.07.	M7.1/2B	31W	05.47	2600		10652	1333	-197(27.07.)	$0.50. 10^{6}$	100-300
08.11.2004	7%	06.11.	M9.3/2N	08E	01.50	1400		10696			$1.64. 10^{7}$	50-100
		07.11.	X2.0/2N	17W	16.27	3500		10696			$1.14. 10^{7}$	100-300
		08.11.	M2.3/1N	35W	15.45	1300		10696	2000			
		10.11.	X2.5/3B	49 W	02.10	6800	g	10696	3387	-400(08.11.)	$6.10. 10^{7}$	50-100
17.01.2005	11%	15.01.	M8.4/2N	06E	04.31	1600		10720			$4.30. 10^{7}$	100-300
		15.01.	X2.6/3B	05W	23.08	13000	g	10720	2861			
		15.01.	X1.2/1B	10E	00.43	3000						
		17.01.	X3.8/2B	25W	09.43	17000	g	10720	2094		$4.60. 10^{7}$	100-300
		19.01.	X1.5	47W			g	10720	2020		$1.79. 10^{8}$	300-800
21.01.2005	11.2%	20.01.	X7.1/2B	61W	06.44	53000	g	10720	882	-105(22.01.)	$3.41. 10^{8}$	300-800
24.08.2005	6.4%	22.08.	M5.6/1N	60W				10798	2378		$3.70. 10^{7}$	100-300
		25.08.	M6.4/1N	79E				10803			$0.90. 10^{7}$	100-300
11.09.2005	13%	07.09.	X17/3B	89E	17.40		g	10808			$1.40. 10^{7}$	25-50
		09.09.	X1.2	64E	20.02		g	10808	2257		$1.31. 10^{8}$	3-6
		10.09.	X1.1	47E	16.39	1600		10808			$5.00. 10^{6}$	25-50
		10.09.	X2.1	47E	21.57	1000	g	10808	1893	-120 (10.09.)	$6.40. 10^{7}$	50-100
		13.09.	X1.7	01E	23.23		g	10808		-147(11.09.)	$2.80. 10^{7}$	100-300
08.12.2006	2.5%	06.12.	X9/2N	79E	10.35			10930			$5.21. 10^{7}$	300-800
	4.5%	13.12.	X3.4/4B	23W	02.40	3550	GLE	10930	1774	-146(15.12.)	$1.79. 10^{8}$	100-300