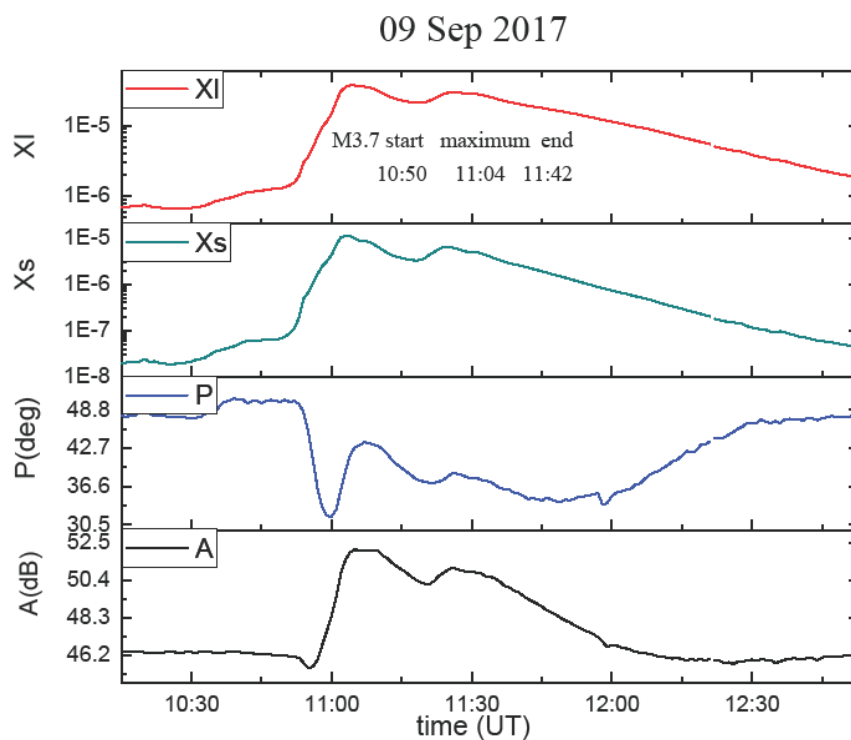


# Supplement material

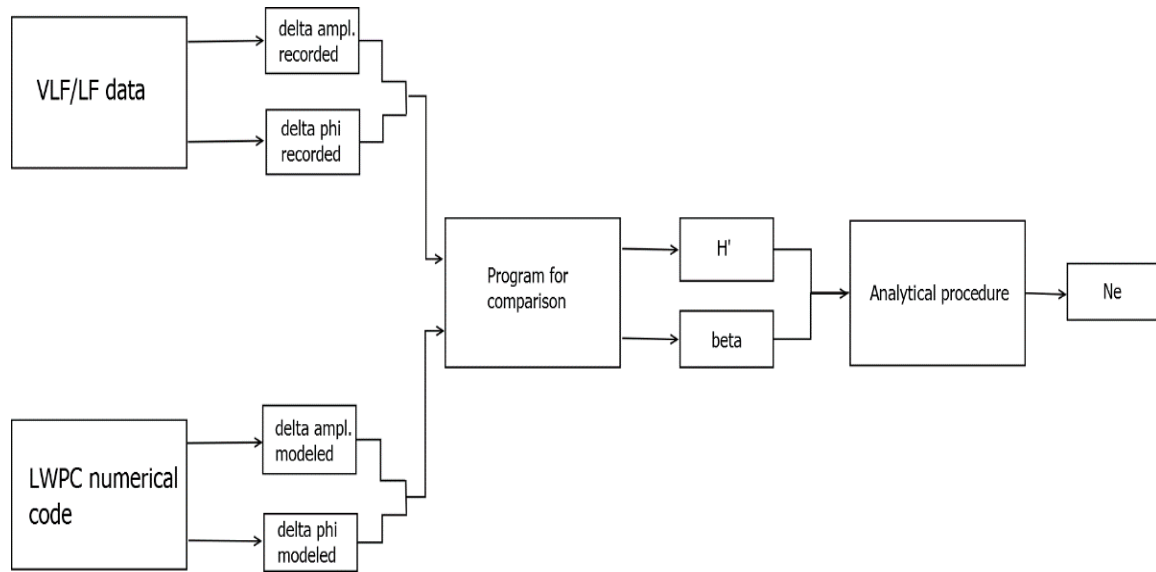
**Table S1.** VLF receiving and transmitting sites.

	Freq(kHz)	Country	Geographic latitude (deg)	Geographic longitude(deg)	GCP(km)	propagation path
<b>Transmitter:</b> <b>GQD</b>	22.10	UK	54.73 N	2.88 W	1982	Northwest to southeast
<b>Receiver:</b> <b>BEL</b>		Serbia	44.85 N	20.38 E		

09 Sep 2017



**Figure S1.** X-ray flux (XS and XL band), amplitude and phase of 22.10/kHz GQD signal against universal time during occurrence of M3.7 class solar flare on 09 Sep 2017. (lower panels) Observed amplitude and phase of radio signals measured at Belgrade (upper panels) Time variation of X-ray irradiance measured by GOES-15 satellite on 09 Sep 2017.



**Figure S2.** Schematic presentation of a method for modeling of electron density in D-region.

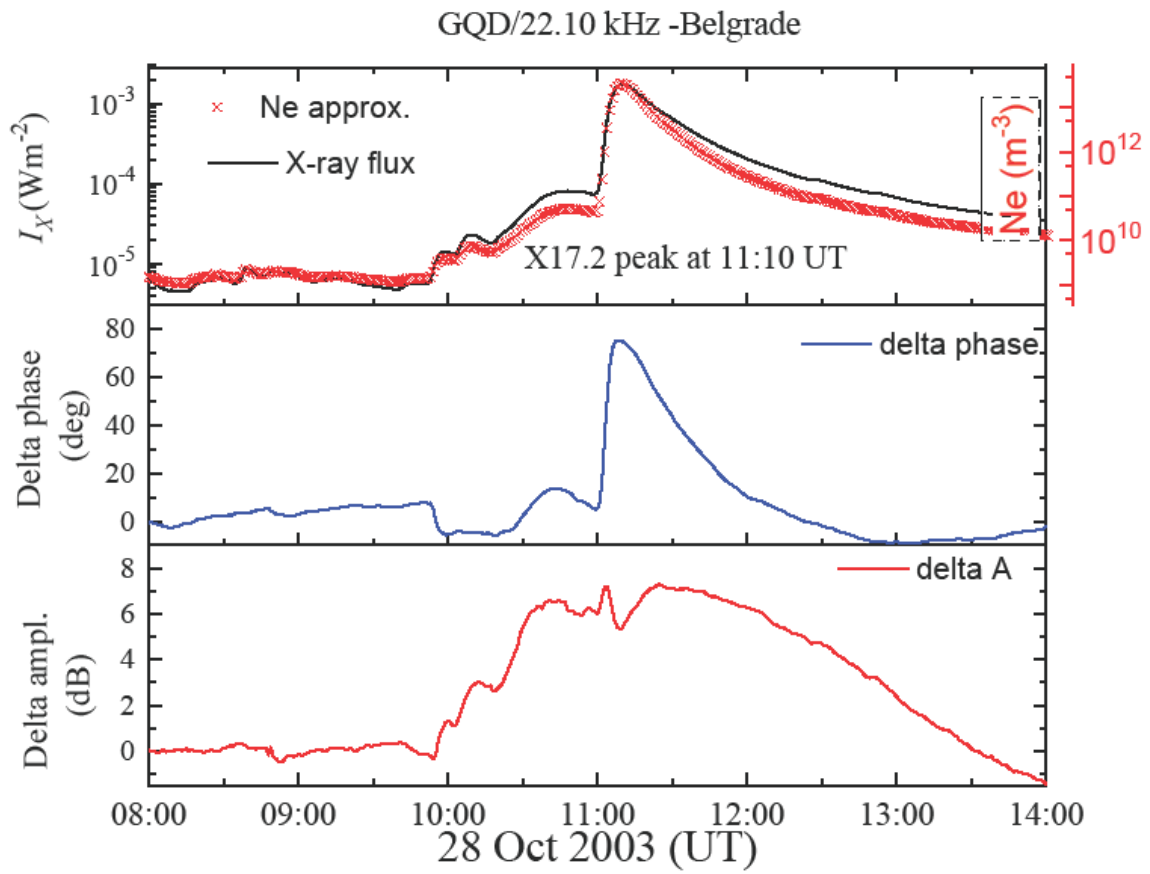
**Table S2.** Data needed for the approximative function (3).

Height (km)	a1(h)	a2(h)	a3(h)
50	10.3249	0.97123	0.06168
51	10.84938	1.10778	0.07203
52	11.37386	1.24433	0.08237
53	11.89835	1.38089	0.09272
54	12.42283	1.51744	0.10306
55	12.94731	1.65399	0.11341
56	13.47179	1.79054	0.12375
57	13.99627	1.92709	0.1341
58	14.52076	2.06364	0.14444
59	15.04524	2.20019	0.15479
60	15.56972	2.33674	0.16513
61	16.0942	2.4733	0.17548
62	16.61868	2.60985	0.18582
63	17.14317	2.7464	0.19617
64	17.66765	2.88295	0.20651
65	18.19213	3.0195	0.21686
66	18.71661	3.15605	0.2272
67	19.2411	3.2926	0.23755
68	19.76558	3.42915	0.24789
69	20.29006	3.56571	0.25824
70	20.81454	3.70226	0.26858
71	21.33902	3.83881	0.27893
72	21.86351	3.97536	0.28927
73	22.38799	4.11191	0.29962

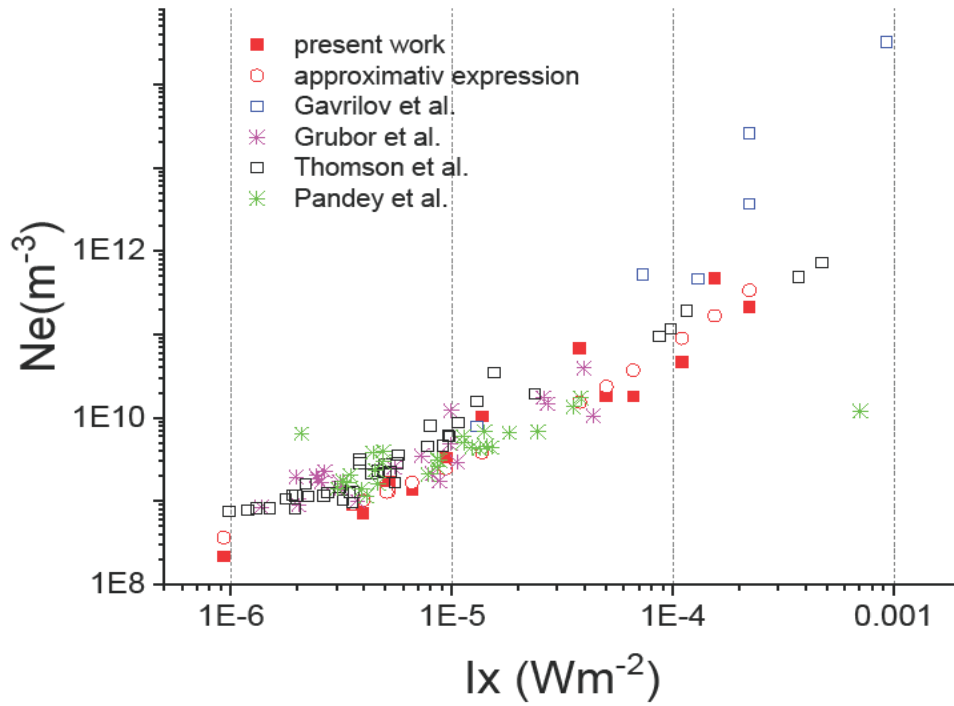
74	22.91247	4.24846	0.30996
75	23.43695	4.38501	0.32031
76	23.96143	4.52156	0.33065
77	24.48592	4.65812	0.341
78	25.0104	4.79467	0.35134
79	25.53488	4.93122	0.36169
80	26.05936	5.06777	0.37203

One of the largest solar flare :

measured with instruments occurred on 28 Oct 2003 (X17.2 class SF,  $I_x = 1.72 \text{ E-3 Wm}^{-2}$ ).



**Figure S3.** (upper panel) Variation of X-ray flux, as measured by GOES-15 satellite, and the corresponding electron density evaluated (Equation 3) at reference height versus universal time UT on 28 Oct 2003 during occurrence of huge X17.2 class solar flare. (lower panels) Perturbation of amplitudes and perturbation of phases on the same day.



**Figure S4.** The electron density  $Ne$  at reference height (red squares) calculated for this study and data obtained by approximativ formula (3) (red circles) are plotted together with the results of other authors [53-56] using Equation (1) and parameters in Figures 12 and 13 from the main text.

**Table S3.** Data of amplitude and phase perturbations of VLF signal and ionospheric parameters induced by different SF events analyzed in this study.

Path: GQD-BEL							
Date	Peak Time [UT]	$I_x$ [Wm <sup>-2</sup> ]	SID VLF data		Obtained data by method from this paper		
			$\Delta A$ [dB]	$\Delta P$ [deg]	$\beta$ [km <sup>-1</sup> ]	$H'$ [km]	$Ne$ [m <sup>-3</sup> ]
		5E-7	0	0	0.30	74.0	2.18E+8
2013/04/26	12:57	<u>C3.57</u> 3.57E-6	-1.85	-3.0	0.36	70.0	9.12E+8
2014/06/10	08:25	<u>C3.9</u> 3.97E-6	-1.5	+0.1	0.36	70.7	7.09E+8
2014/06/10	10:17	<u>C5.0</u> 5.06E-6	-0.5	-9.0	0.39	69.1	1.46E+9
2014/06/10	09:31	<u>C5.1</u> 5.18E-6	-2.0	-7.0	0.41	68.95	1.71E+9

2013/05/01	14:14	<u>C6.6</u> 6.6E-6	-1.9	-6.9	0.38	69.1	1.39E+9
2011/02/14	12:53	<u>C9.4</u> 9.4E-6	-1.5	-14.0	0.42	67.5	3.31E+9
2013/05/10	12:56	<u>M1.3</u> 1.37E-5	+0.85	-19.4	0.45	65.4	1.04E+10
2017/09/09	11:04	<u>M3.7</u> 3.78E-5	+5.6	-5.6	0.49	62.5	6.7E+10
2013/05/22	13:32	<u>M5.0</u> 5.0E-5	+2.64	-17.0	0.46	64.4	1.79E+10
2011/02/18	10:11	<u>M6.61</u> 6.61E-5	+3.51	-9.0	0.44	63.95	1.80E+10
2014/06/11	09:06	<u>X1.1</u> 1.1E-4	+5.1	+5.0	0.46	62.3	4.70E+10
2014/06/10	12:52	<u>X 1.5</u> 1.55E-4	+7.4	+15.0	0.53	61.0	2.12E+11
2014/06/10	11:42	<u>X2.2</u> 2.22E-4	+7.3	+32.0	0.52	59.2	4.75E+11