SIMULTANEOUS OBSERVATIONS OF THE IAR WAVE STRUCTURE AT THE MID-LATITUDE AND AURORAL STATIONS

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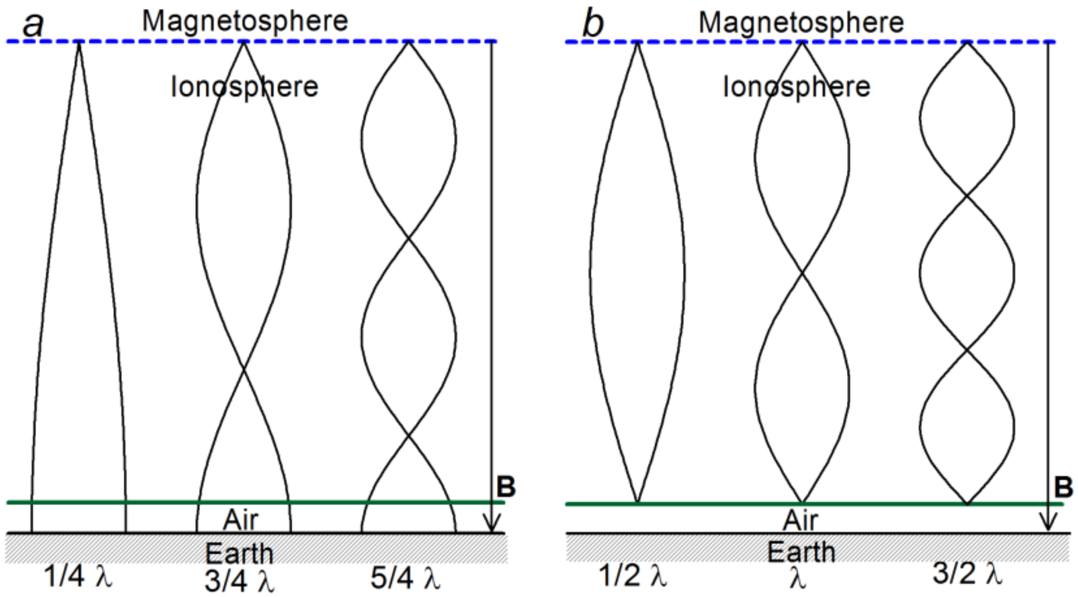
Type 1 — Type 2

$1/k_{\perp} >> \Delta h_{Air}$ — $1/k_{\perp} << \Delta h_{Air}$



Two types of structure of standing Alfvén waves in the IAR. The nominal configuration of the wave magnetic field for the first three harmonics is shown. The left panel *a* corresponds to the case when the reflection coefficient from the lower boundary of the resonator is $R = -1$; frequencies ratio is 1:3:5 (Type 1). The right panel *b* corresponds to the case $R = +1$: frequencies ratio is 1:2:3 (Type 2).

According to the idealized IAR model [Polyakov and Rapoport, 1981], the frequency f_n of the n-th harmonic can be written in the form

$$f_n = \frac{(n+\Phi)\cdot c_A}{2L}, \tag{1}$$

From (1), we have

$$\kappa = \frac{f_{n+m}}{f_n} = \frac{n+m+\Phi}{n+\Phi}, \tag{2}$$

m, the same as n are integers. From (2), it follows

$$\Phi = \frac{n(1-\kappa)+m}{\kappa-1}. \tag{3}$$

For $n=m=1$ (ratio of the second harmonic frequency to the first one) we have

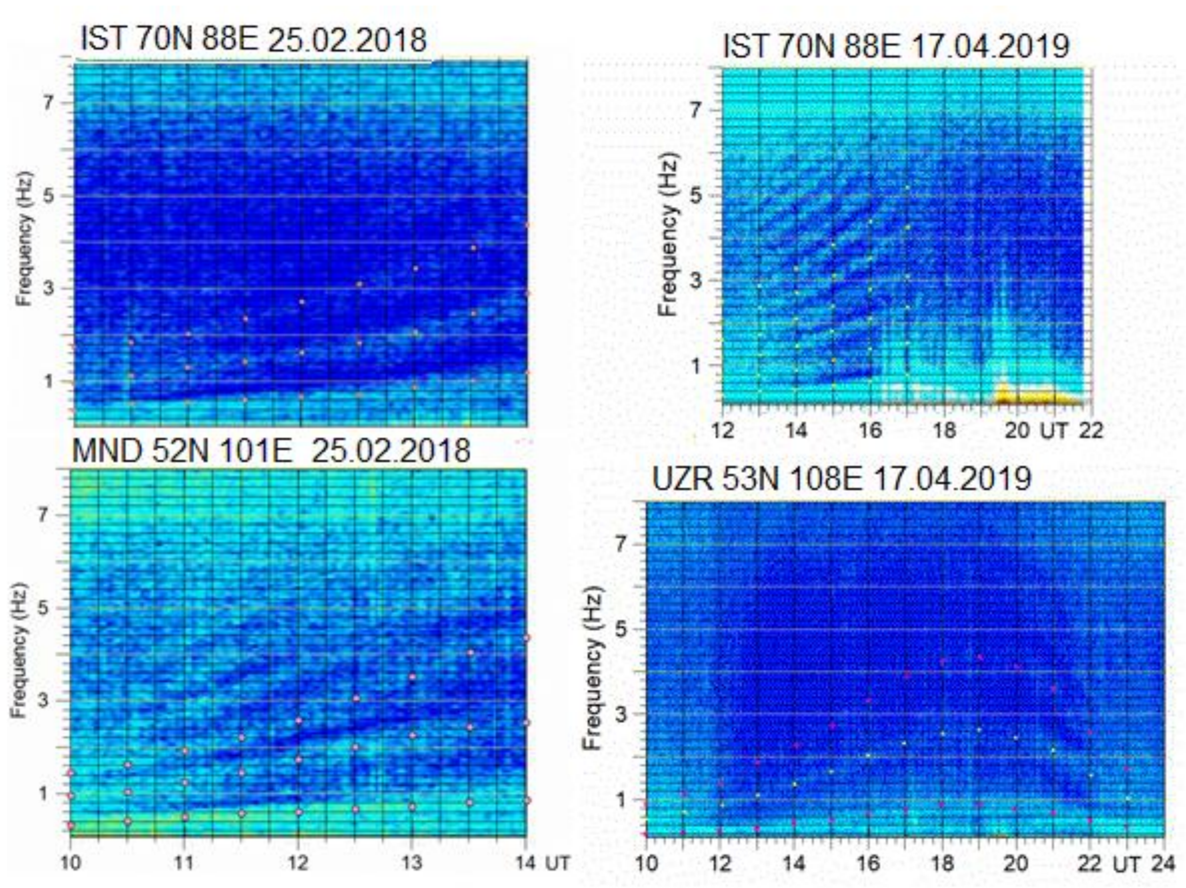
$\kappa = f_2/f_1$, $\Phi = (2-\kappa)/(\kappa-1)$, respectively

Type 1	Type 2
(antinode below)	(node below)
$\kappa = f_2/f_1 = 3$	$\kappa = f_2/f_1 = 2$
$\Phi = -1/2$	$\Phi = 0$

For $n=1$, and $m=2$ (ratio of the third harmonic frequency to the first one)

$\kappa = f_3/f_1$, $\Phi = (3-\kappa)/(\kappa-1)$, respectively

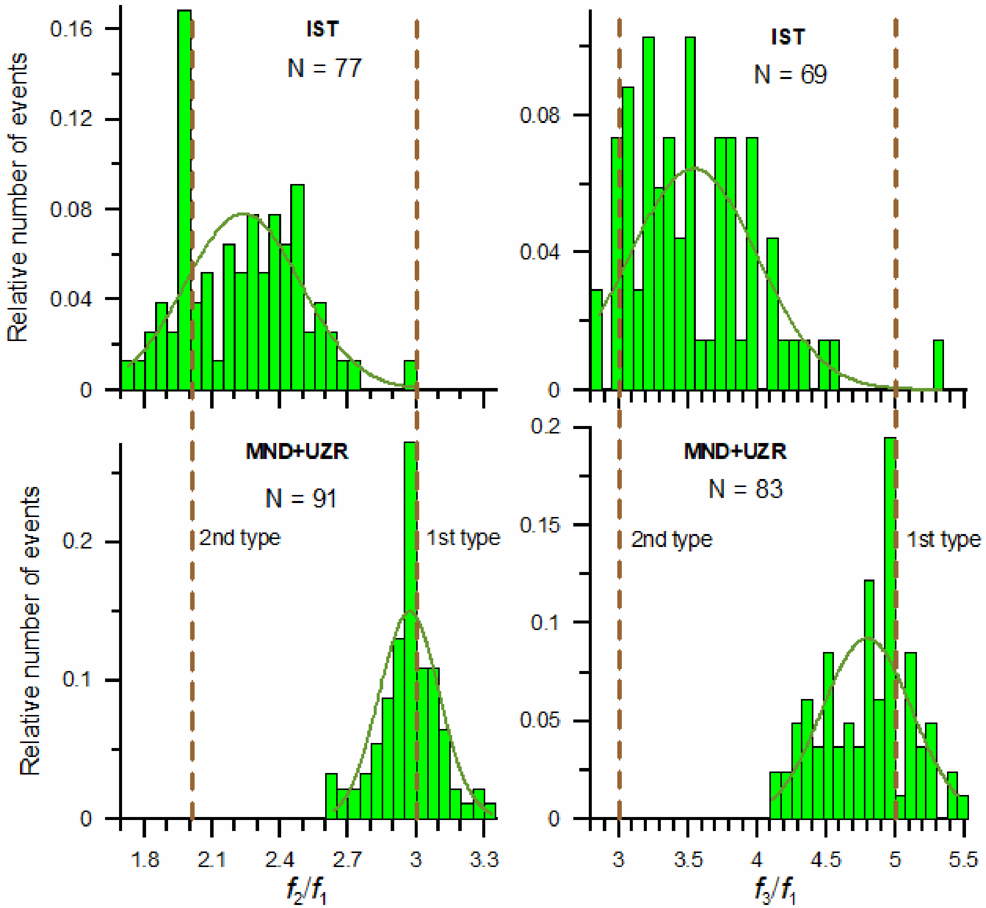
$\kappa = f_3/f_1 = 5$	$\kappa = f_3/f_1 = 3$
$\Phi = -1/2$	$\Phi = 0$



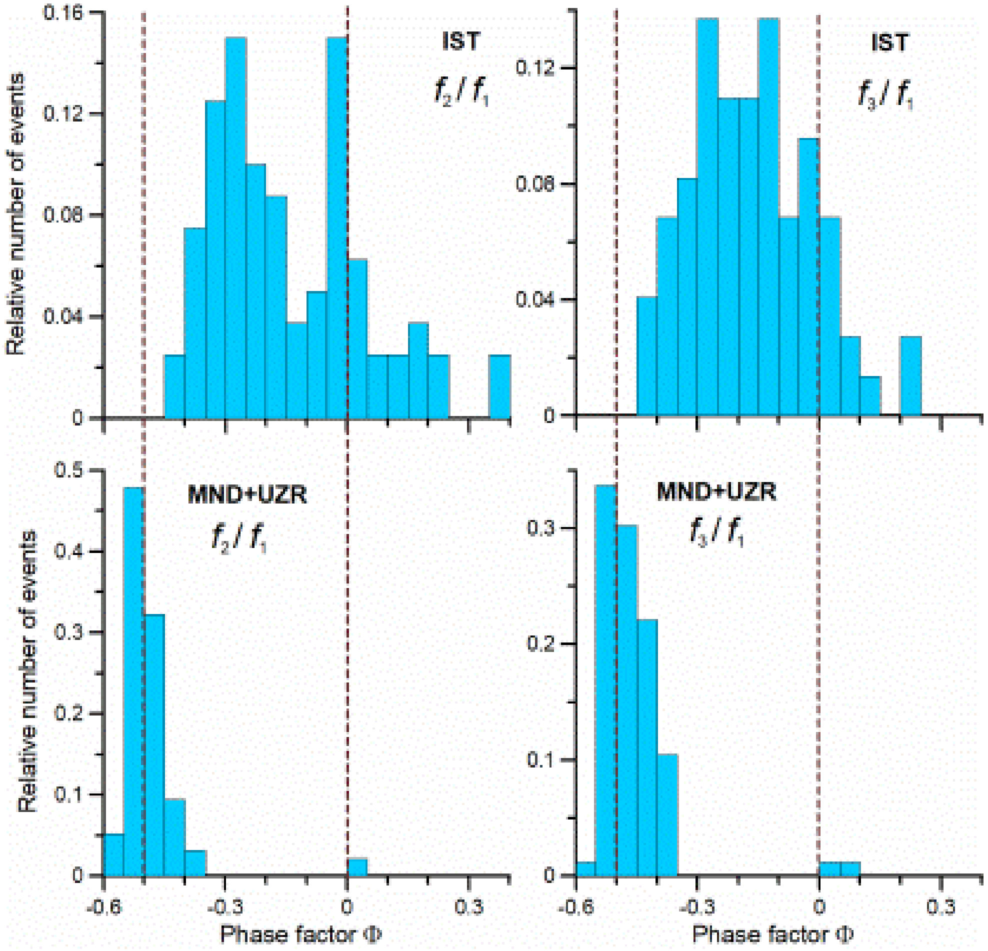
Comparison of simultaneous IAR mode at mid- and high-latitude stations. Colored dots are marked for subsequent digitization of the daily variation of the harmonic frequency. Right upper panel: At the IST station, from approximately 16:20 UT, irregular oscillations are visible in the frequency range up to 0.5–3.5 Hz, caused by weak auroral activity (auroral agitation). No traces of auroral activity were detected at the UZR.

Table lists the serial numbers of events, dates, abbreviations of stations, observation intervals at middle and high latitudes.

#	Date	Station	UT interval	$\langle f_2/f_1\rangle$	$\langle f_3/f_1\rangle$	Date	Station	UT interval	$\langle f_2/f_1\rangle$	$\langle f_3/f_1\rangle$
Mid-latitude stations MND (52N, 101E) and UZR (53N, 108E)						**High-latitude** station IST (70N, 88E)				
1	25_Feb_2018	MND	10-14	3.01	4.70	25_Feb_2018	IST	10-14	2.41	3.98
2	08_Mar_2018	MND	10-17	2.90	No data	08_Mar_2018	IST	10-16	2.49	4.10
3	25_Apr_2018	MND	12-18	2.96	4.61	25_Apr_2018	IST	12-18	1.85	3.15
4	10_Jul_2018	MND	16-22	3.07	4.65	10_Jul_2018	IST	17-24	2.01	3.23
5	06_Aug_2018	MND	11-16	2.99	4.97	06_Aug_2018	IST	11-18	2.10	3.31
6	10_Aug_2018	UZR	12-20	3.02	4.79	10_Aug_2018	IST	12-20	2.25	3.46
7	17_Oct_2018	MND	08-17	2.99	4.67	17_Oct_2018	IST	10-17	2.11	3.23
8	16_Apr_2019	UZR	11-24	2.98	4.77	16_Apr_2019	IST	14-21	2.44	No data
9	17_Apr_2019	UZR	10-22	3.02	5.05	17_Apr_2019	IST	12-17	2.16	3.36
10	18_May_2019	MND	13-23	2.86	4.76	18_May_2019	IST	13-23	2.41	3.84
			Mean	**2.98**	**4.77**				**2.22**	**3.52**
			Mean st. err.	**0.02**	**0.05**				**0.07**	**0.12**



Histograms show event distributions according to the ratio of frequencies of harmonics. The bottom row shows distributions over the ratio of second to first harmonic (left) and third to first harmonic (right) at the mid-latitude stations. Top row shows the same distributions at the high-latitude IST station. The brown dashed lines indicate ratios expected for Type 1 or Type 2 of Alfvén wave structure trapped in the resonator with an antinode or node of standing waves at the lower boundary, respectively.



Histograms of event distributions by phase factor Φ calculated using formula (4). The bottom row shows the distributions of events according to observation data at the mid-latitude stations, while the top row shows the distribution of events by Φ at the IST high-latitude station.

Mid-latitude ionosphere

Homogeneity → $1/k_{\perp} >> \Delta h_{Air}$ (IAR transverse size >> Air gap) **→ $f_1 : f_2 : f_3$ = 1:3:5**

(Type 1 of wave structure) Oscillations freely penetrate to the earth surface

High-latitude ionosphere

Strong Inhomogeneity → $1/k_{\perp} << \Delta h_{Air}$ (IAR transverse size << Air gap) **→ $f_1 : f_2 : f_3$ = 1:2:3**

(Type 2 of wave structure) Oscillations almost do not penetrate to the earth surface

Weak Inhomogeneity → $1/k_{\perp} \approx \Delta h_{Air}$ (IAR transverse size **~** Air gap) **→ $f_1 : f_2 : f_3$ = ?:?:?**

(Intermediate structure) Oscillations partially penetrate to the earth surface

Conclusions

1. The ratio of harmonic frequencies in mid-latitudes is always close to the series of odd numbers, while in high latitudes it takes intermediate values between the series of natural numbers and odd numbers.
2. The wave structure of the IAR at high latitude is disrupted even by relatively weak auroral disturbances.
3. IAR emissions at high latitude are much rarer phenomenon than at mid-latitudes.

Thank you for attention!