HIGHER HARMONIC PLASMA RADIATION IN TYPE II SOLAR RADIO BURSTS

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The large behind -limb (W 140, 0900 UT) flare on February,16, 1984 was followed by a complex of radio bursts - type II, III, IV and V bursts.

TWO MAIN PECULIARITIES:

1. U - SHAPED DYNAMIC SPECTRUM - the propagation of shock wave along the coronal loop, connecting AR 4408 and AR 4410(W 95). Radio source - quasi parallel shock wave.
2. SIMULTANEOUS EMISSION OF THREE (OR FOUR) NEARLY HARMONICALLY RELATED BANDS (A - D).

	t_1	t_2		t_1	t_2		t_1	t_2
f_A/f_D	5.1	5.1	f_A/f_C	3.2	2.9	f_A/f_B	1.8	1.6
f_B/f_D	2.9	3.3	f_B/f_C	1.8	1.9	f_B/f_C	1.8	1.9
f_C/f_D	1.6	1.7				f_C/f_D	1.6	1.7

Frequency ratios for t_1 =09:00:50 UT and t_2 =09:03:50 UT.

Several possibilities of a connection between the bands:

<u>2.1. Splitted F - H burst.</u> Bands C, D are the fundamental component and bands A, B are the second harmonic component of type II burst with band splitting. This interpretation is inconsistent with the frequency ratios.

<u>2.2. Two F - H bursts.</u> Two coaligned emitting loops should be exist, and their densities differ by factor $(f_B/f_D)^2 \sim 10$.

<u>2.3. Simple harmonik system.</u> If the basic band is band D, then the fourth harmonic is missed. If the basic band is band C, the correspondence to the observed frequensy ratios is good, band D must be another type II burst. The herringborn structure in band B is not a duplicate of the structure in band C.

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2.4. Double resonanse. Generation at the levels where the condition $f_{uh}/f_{ce}=n$ (n=1,2...) is fulfilled. Bands at lower frequency should be exited with a time delay during the outward propagation of the shock wave, which is not observed.

2.5. Successive harmonics. Each of bands A,B,C is the near-harmonic of its low-frequency neighbour (B,C,D respectively). The generation of band B would then require the following interaction

$$t(\leq 2f_{pe}) + t(\leq 2f_{pe}) \pm \mu \longrightarrow t(\leq 4f_{pe} \pm f_{\mu})$$

μ is unspecified, probably e.m. mode.
However, the process with one transverse wave near f_{pe} is also possible. Two bands near f_B would result. Moreover, excitation of band A by coalescence of waves in band B would be negligible in comparison to coalescence of waves in band B with waves in the much more intence bands C and D. We have thus to abandon this hypothesis.

2.6. Wave decay and coalescence. This mechanism includes generation e.m. waves at 3/2 f_{pe} according to scheme

$$t(f_{pe}) \longrightarrow l(f_{pe}/2) + l(f_{pe}/2)$$
$$t(f_{pe}) + l(f_{pe}/2) \longrightarrow t(3f_{pe}/2)$$

Such a sheme works also for e.m. waves at $2f_{pe}$ to produce emission at $3f_{pe}$. Four emisssion bands can result with frequency ratios 1:1,5:2:3, which differ clearly from the the registrated ratios.

2.7. Modified harmonic system. The bands A-D are a harmonic system produced in part by four-wave interaction with appropriate shift off the integer harmonics. Suppose that, besides the Langmuir waves (or possibly uh-waves) an e.s. wave mode σ at frequencies $f_{pi} << f < f_{pe}$ is excited to a nonthermal level in the source volume. Then the four-wave interaction

$$l + t(\approx n f_{pe}) + \sigma \longrightarrow t(\approx (n+1)f_{pe}),\ n \geq 2$$

may be most effective in producing higher harmonics. More preciesely, transverse waves near $f = nf_{pe} + (n-2)f_{\sigma}$ are upconverted to transverse waves near $f = (n+1)f_{pe} + (n-1)f_{\sigma}$ for $n \geq 2$.
Test of hypothesis (2.7). The most probable candidate for mode σ are the e.s. electron cyclotron harmonic waves (CHW). Since instabilities of the CHW show the tendency to possess the lowest thresholds and highest growth rates in the lowest passbands $n < f/f_{ce} < n+1$; n=0,1, we put $f_{\sigma} \sim (0.5\text{-}1.5)f_{ce}$. In order to obtain a marked frequency shift, the ratio f_{pe}/f_{ce} must not be too large; we choose $f_{pe}/f_{ce} \sim 3$. The combination of one of the processes $l \pm s \longrightarrow t(\approx f_{pe})$ or $l \longrightarrow t(\approx f_{pe})$ for fundamental emission with the process $l + l' \longrightarrow t(2f_{pe})$ for the second harmonic generation and four-wave interaction for higher harmonic generation is capable to yield rough agreement with all observed ratios. However, this conformity is obtained only for $f \geq 0.5\ f_{pe}$.

CONCLUSION. The possibility of frequency-shifted higher harmonic plasma radiation, discussed here, where the occurence and frequency shift of the higher harmonics are both related to the nonthermal excitation of an appropriate mode at "intermediate" frequencies, should revive the search for higher harmonics in solar radio bursts.