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Modelling modulation masking between frequency modulation and amplitude modulation

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Introduction

Frequency modulation (FM) may be detected as amplitude modulation (AM) as the excitation pattern on the basilar membrane changes.

Thus, FM detection in the presence of an AM masker should exhibit the main features of AM masking: tuning, AM-masker depth dependency, beating and phase effects (e.g., Strickland & Viemeister, 1996).

If this is the case, the features of masking of FM by AM should be predictable by models of AM processing (Dau et al., 1997).

Methods

Participants:

Ten (seven female) normal-hearing listeners (20 - 30 years old; mean 25.5 years).

Procedure:

- 2I-2AFC, two-down, one-up staircases adapting frequency excursion (in Hz) multiplicatively.
- Threshold = geo. mean of last 8 of 12 reversal points.
- One staircase on all conditions as training, then geo. mean of three staircases for each condition.
- Feedback was provided.
- Stimuli presented at 65 dB SPL to the right ear.

Results

Masking: FM detection threshold with AM masker (FM_{wAM}) divided by FM detection threshold without AM masker (FM_{noAM})

Tuning and beating :: 10 listeners

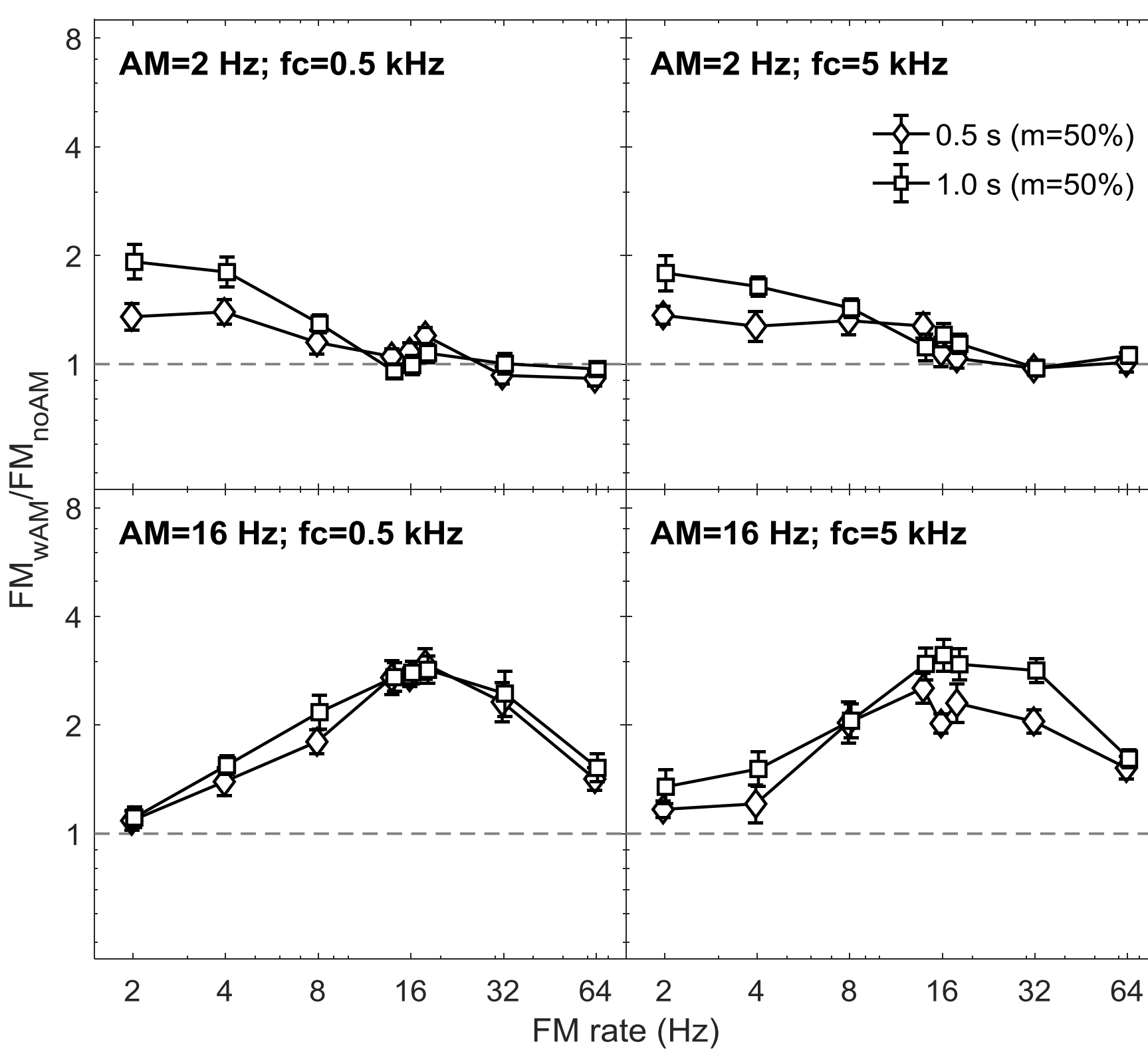


Fig 1: The mean masking produced by AM as a function of FM rate. Diamonds and squares denote 500 s and 1 s stimulus duration, respectively. Error bars are ± 1 standard error. (FM and AM were in phase, but a random phase selected for each trial.)

AM masker depth :: 5 listeners

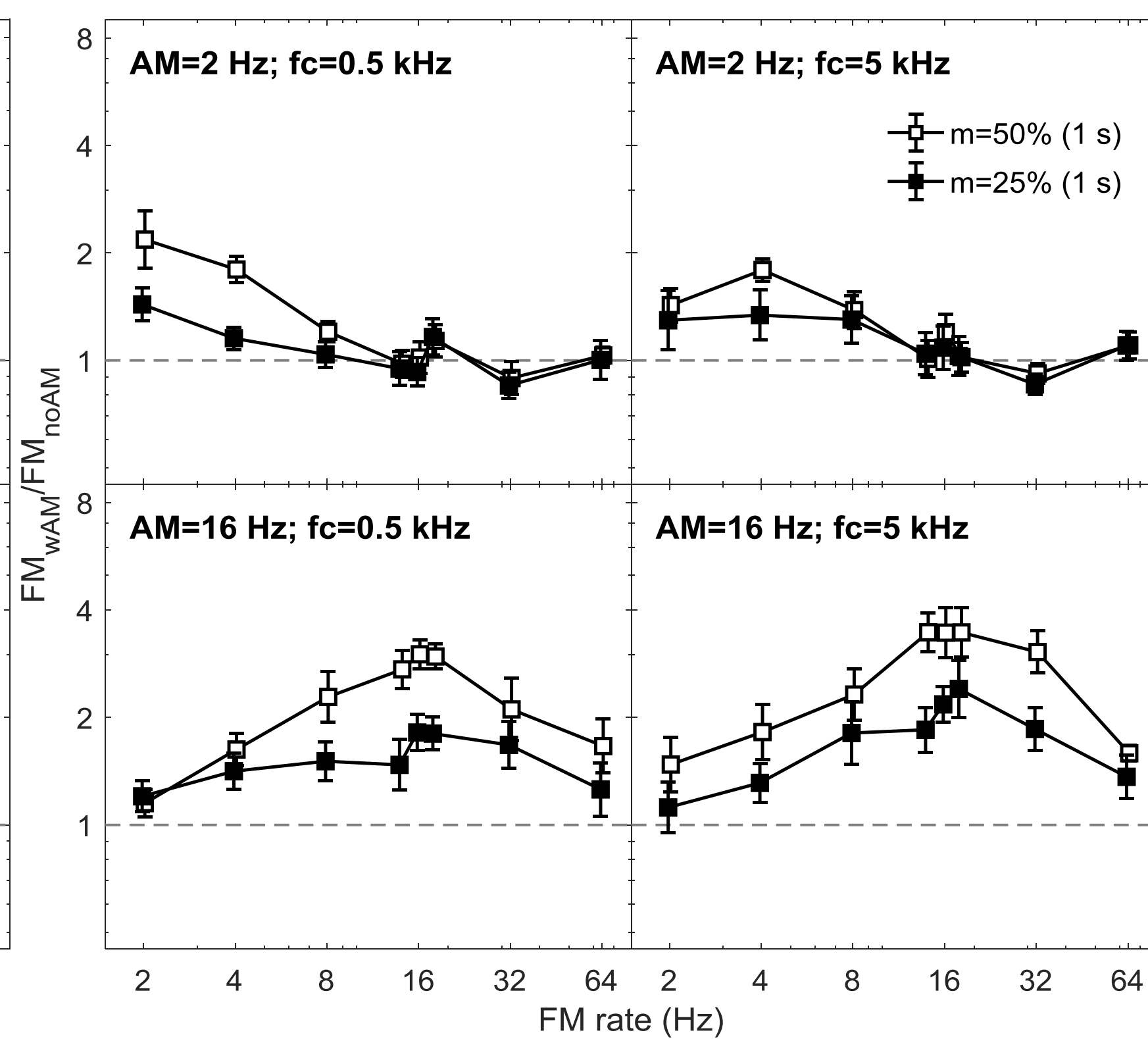
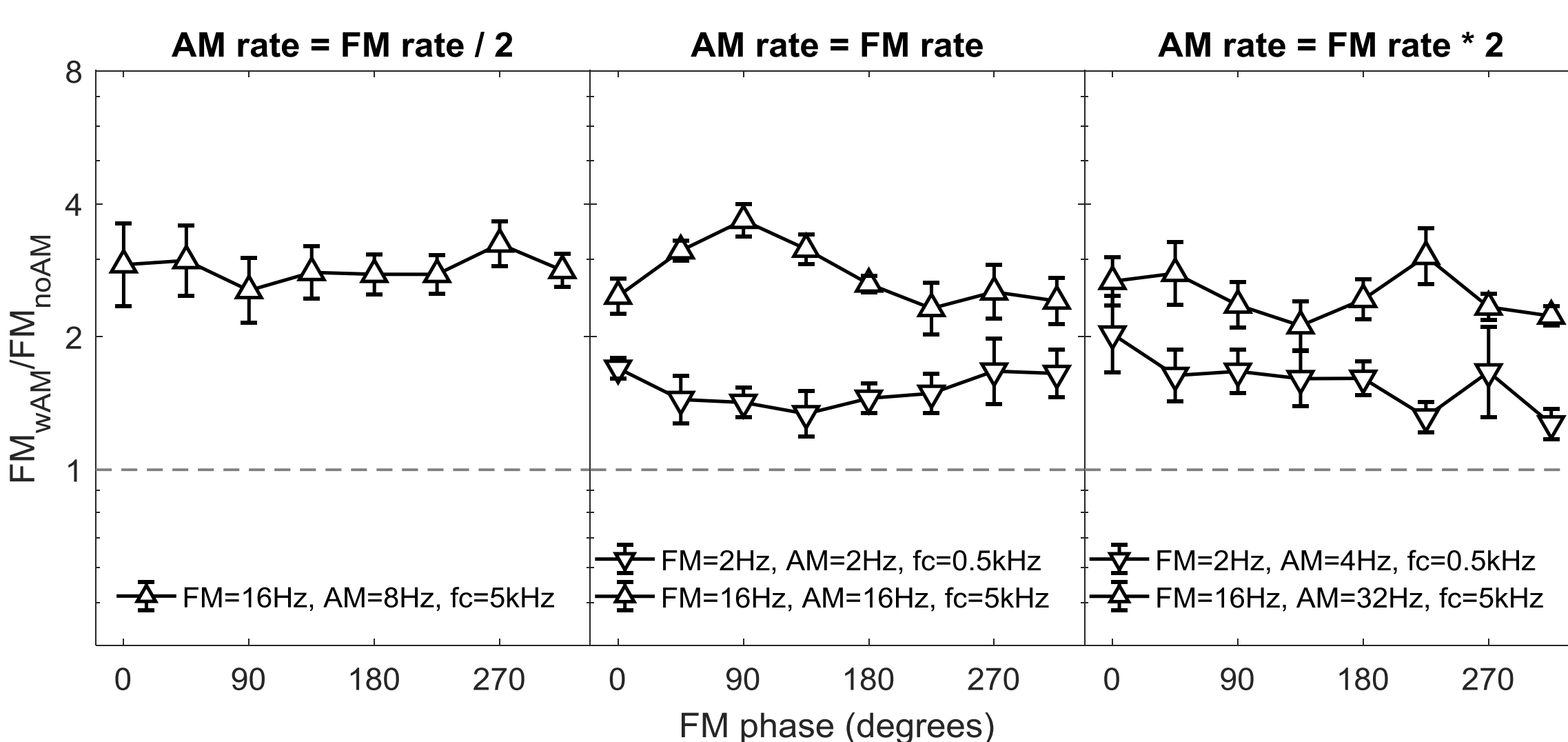


Fig 2: The mean masking produced by AM as a function of FM rate. Open and filled squares denote 50% and 25% AM depth, respectively. Error bars are ± 1 standard error. (FM and AM were in phase, but a random phase selected for each trial.)

Phase effects :: 6 listeners



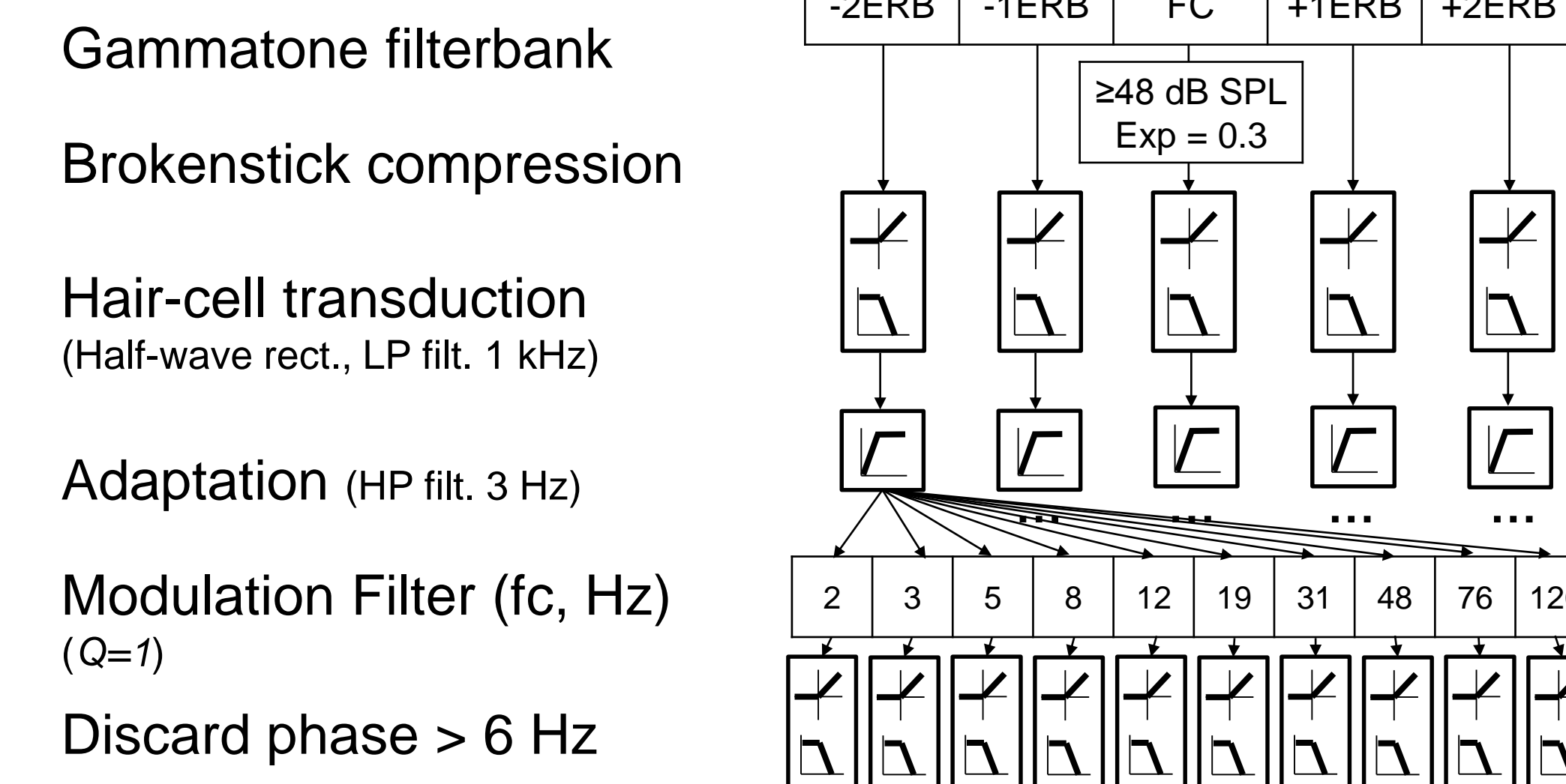
Masking effects observed:

- Tuning**
 - Tuned to masker rate: 3- and 2-fold increases at 16-Hz and 2-Hz.
- Beating effects**
 - No reduction in masking at 14 and 18 Hz for 16-Hz masker.
- AM-masker depth dependency**
 - AM at 25% depth produced less masking than 50% depth.
- Phase effects**
 - A peak in masking (at 90° phase) for 16 Hz FM and AM, but no clear effects.

Fig 3: The mean masking effect of AM on FM as a function of phase difference between AM and FM with ± 1 standard error. Upward and downwards facing triangles denote 2 and 16 Hz FM targets respectively. (AM always sine phase and FM phase relative to that.) (Stimulus duration: 1 s.)

Modulation Filterbank Model

Model Specification:



Decision statistic

$$i = GTchan, j = Modchan, \max_{i,j} \left(\frac{\sum_{j=1}^{10} \sum_{i=1}^5 (target_{ij} * template_{ij})[\tau]}{\sum_{j=1}^{10} \sum_{i=1}^5 (standard_{ij} * template_{ij})[\tau]} \right)$$

template = target_i[τ] - standard_i[τ], ignoring AM

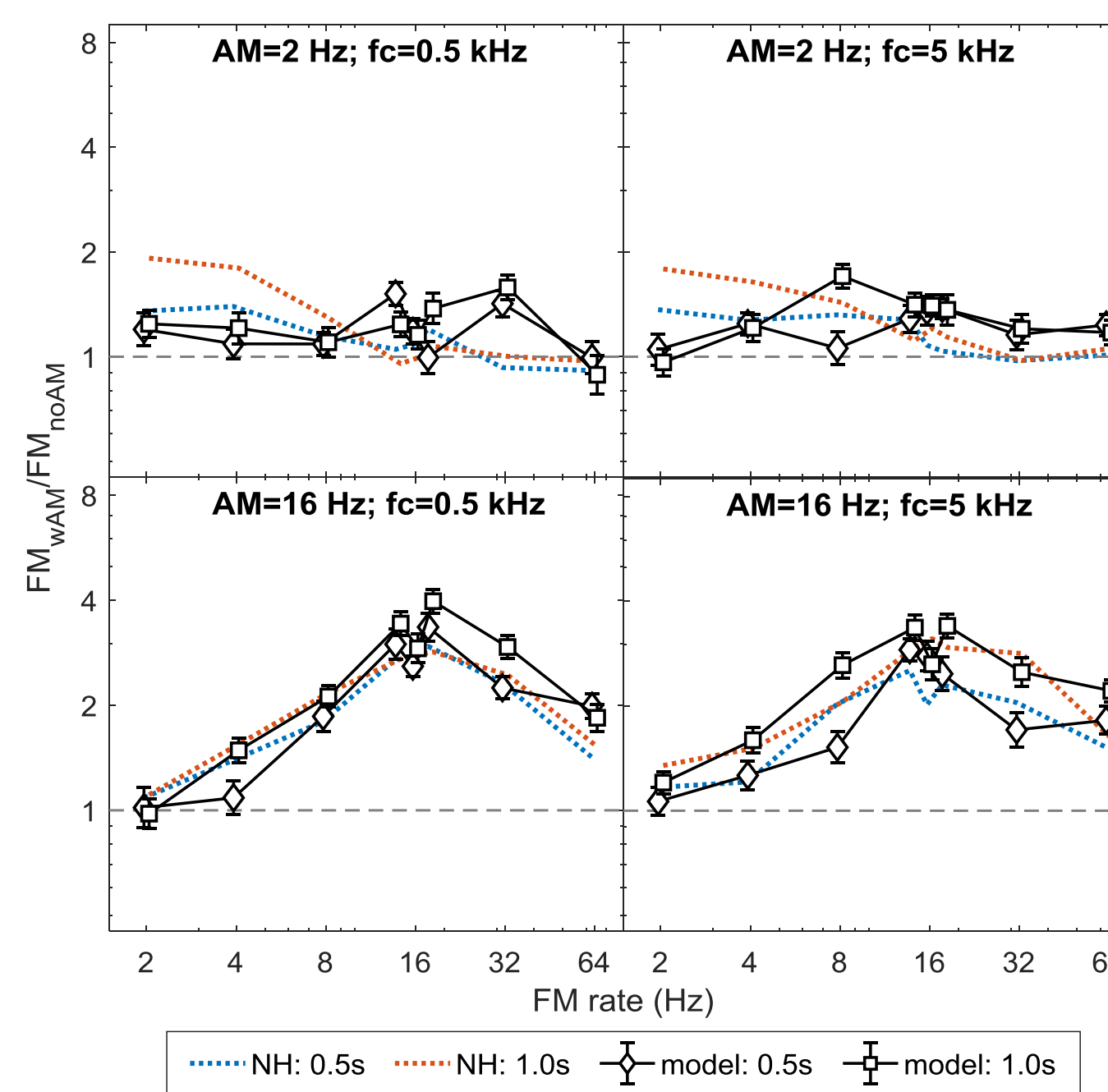


Fig 5: As Fig. 1, but with thresholds simulated by the model. Behavioural data from Fig. 1 replotted as blue and red dashed lines.

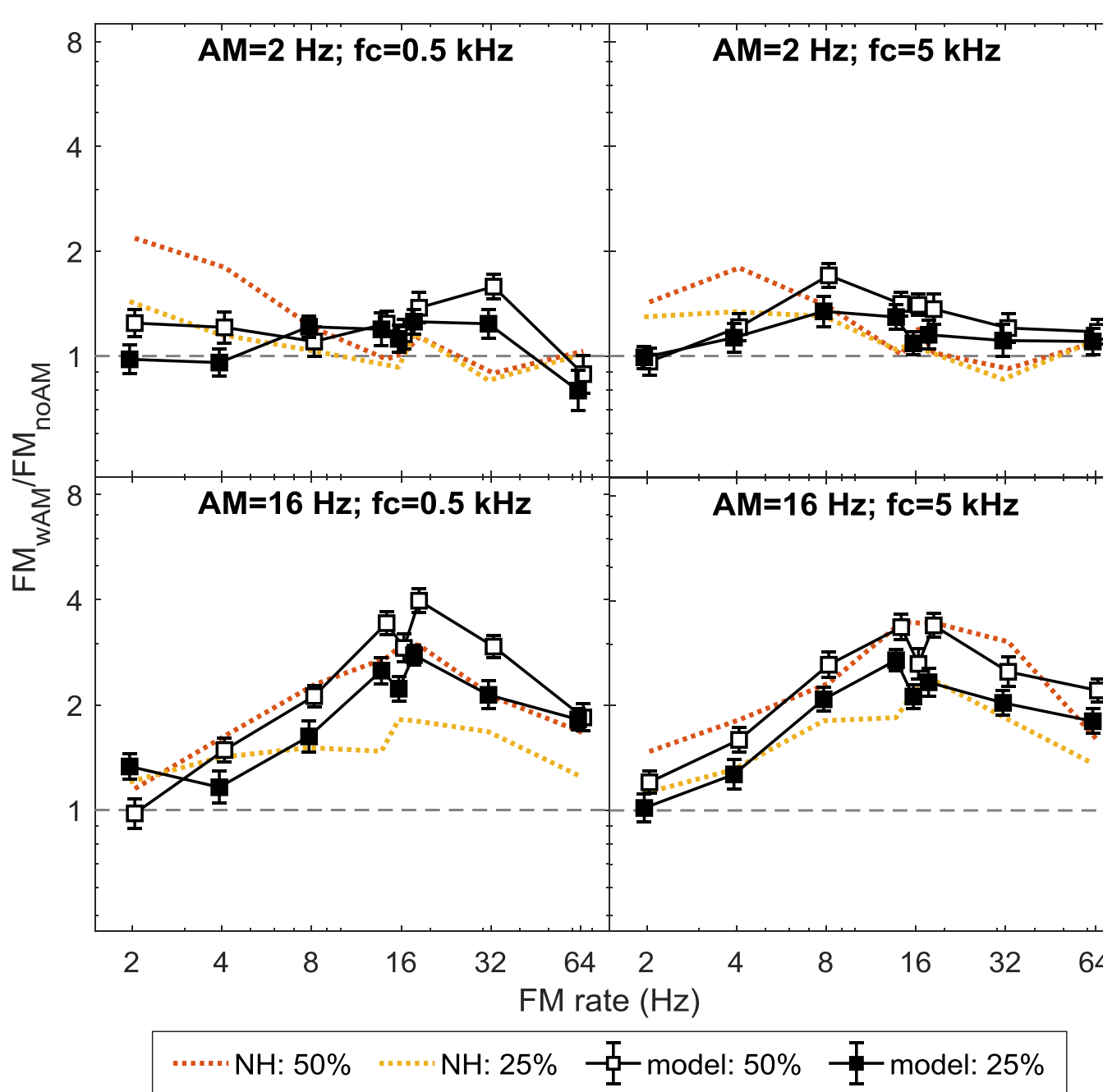


Fig 6: As Fig. 2, but with thresholds simulated by the model. Behavioural data from Fig. 2 replotted as yellow and red dashed lines.

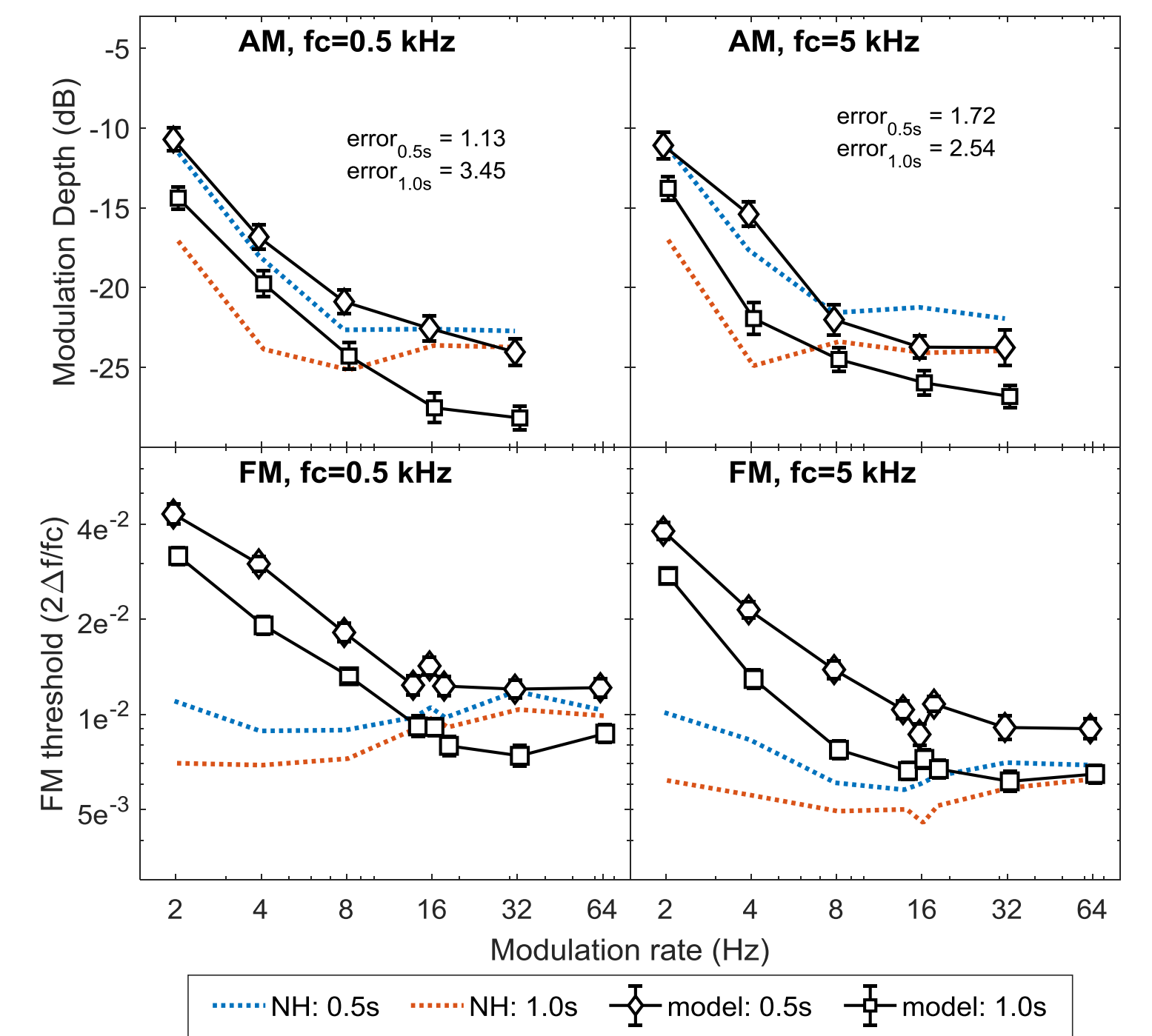


Fig 4: Top panels: AM detection thresholds from the model (open symbols) and mean of 10 listeners (dashed lines) with RMS error between them. Bottom panels: FM detection thresholds (without AM), denoted similarly.

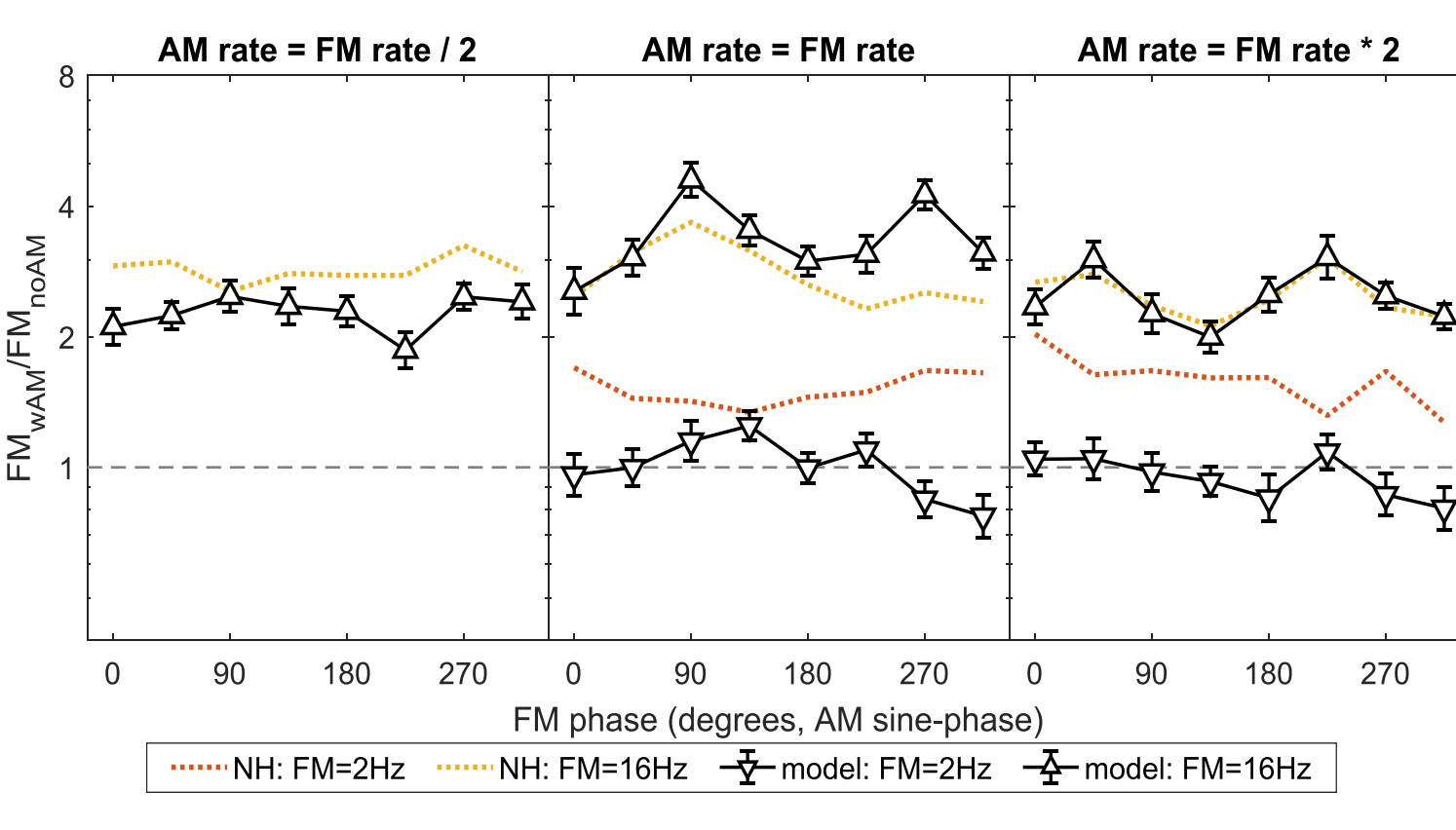


Fig 7: As Fig. 3, but with thresholds simulated by the model. Behavioural data from Fig. 3 replotted as yellow and red dashed lines.

Discussion

- Masking caused by AM on FM detection was frequency selective. For both AM masker rates, masking peaked at the masker rate.
- Increasing AM-masker depth increased masking.
- Beating cues when the FM and AM rates were only 2 Hz apart did not produce release from masking.
- Some changes in masking with phase, but no clear, consistent phase effects.
- The model was able to simulate AM-masking-FM well for a 16-Hz masker, but not for a

2-Hz masker. To simulate masking, the model had to be insensitive to phase at the modulation filter outputs. It also simulated beating effects unless the template ignored the AM masker.

Similar masking patterns were found for the 0.5-Hz and 5-kHz carriers. However, the model using envelope cues only could only account for the 16-Hz AM masking data, and failed to account for the 2-Hz AM data. Overall, this suggests that **separate mechanisms operate for slow and high rate FM detection, but the similar masking effects cast doubt on the role of neural phase-locking cues (TFS cues, e.g., Ernst & Moore, 2010).**

Acknowledgments

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References

- Dau, T., Kollmeier, D., & Kohlrausch, A. 1997. Modeling auditory processing of amplitude modulation: I. Detection and masking with narrow-band carriers. *J Acoust Soc Am*, 102 (5), 2892-2905.
- Ernst, S.M.A. & Moore, B.C.J. 2010. Mechanisms underlying the detection of frequency modulation. *J Acoust Soc Am*, 123 (6), 3642-3648.
- Strickland, E.A., & Viemeister, N.F. 1996. Cues for discrimination of envelopes. *J Acoust Soc Am*, 99 (6), 3638-3646.