MULTITONE INTERMODULATION METHOD FOR SPEAKER TESTING

by Phil Marshall
February 2009

Summary

A single test signal comprising 7 sine waves is proposed with frequencies selected according to a procedure designed to stress the speaker under test to a maximum.
It is appropriate for the most common speaker configurations i.e. 2 way or 3 way designs.
The advantage of this approach is that it is simultaneously sensitive to all the design variables that may effect the linearity of the drivers i.e. crossovers and crossover topology.
The final outcome is a well defined and repeatable single figure of merit which correlates well with listening tests.

Measurements are made with low cost pc based equipment and standard audio software.

1. INTRODUCTION

There are many examples of speaker intermodulation test methods of varying complexity. However, there are no attempts at standardisation or suggestions for an overall figure of merit.

Traditional swept 2 tone tests or simple harmonic distortion tests produce results that are difficult to summarise and they are also incapable of stressing the speaker in the same way as normal music.

For example, a midrange driver covering the range of 400 Hz to 2500 Hz, if tested with a simple 2 tone intermodulation signal at 1000 and 1100 Hz reveals nothing of the simultaneous effect of a similar 1000 Hz tone plus an out of band signal at 300 Hz or 4000 Hz.

This latter combination of signals will produce further intermodulation products that will also depend, in part, on the design of the crossover as well as the driver linearity.

Some methods use a large number of test tones covering the audio range in less than third octave spacings. The primary disadvantage of this technique is that it again diverges too far from the characteristics of typical music. Each tone is at a relatively low level and the set of intermodulation products will be too complex to analyse intuitively.

The speaker needs to see as small a number of test tones as possible in order to produce higher individual levels and equal stresses to each driver.

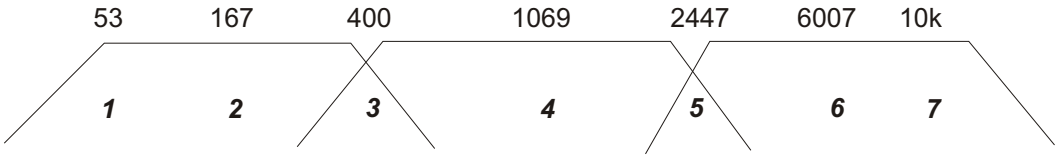


FIG 1 Test Tone example for 2 or 3 way speakers

2. TEST TONE DESIGN

The basic requirements are:

1. **Place tones at the extremes of 53 and 10 kHz**
2. **At each crossover point**
3. **At regular intervals roughly in proportion to the bandwidth of each driver.**

FIG 1. is an example of a suitable selection of signals for a 2 way design with a crossover at 2500 Hz, or a 3 way design with crossovers at 400 and 2500 Hz.

Frequency selection is based on the following suggested criteria

Tone 1: Normally 53 Hz. If this coincides with a vented speaker port tuning, select an alternative between 40 and 60 Hz away from the resonance.
Tone 2: Normally 167 Hz or close to the geometric mean of tone 1 and 3.
Tone 3: Typically 400 Hz or at the woofer / midrange crossover point.
Tone 4: Typically 1069 Hz close to the geometric mean between tones 3 and 5.
Tone 5: Typically 2447 Hz at the midrange / tweeter crossover point.
Tone 6: Typically 6007 Hz close to the geometric mean between tones 5 and 7.
Tone 7: Normally 10 kHz

When selecting tones 1 to 4 it is suggested that they are based on prime numbers to minimise the overlap of harmonics and intermodulation products. Table 1 in the appendix has a list of prime numbers up to 4000.

All tones are of equal amplitude typically -10 dB below digital clipping levels.

3. MEASUREMENT TECHNIQUE

A good familiarity is assumed with the use of pc based sound recording and editing . The sequence is as follows:

1. Play back the required test tone at a level equivalent to 90 dBA at 1m.

2. Record the test tone in a quiet environment, using a good quality condenser microphone at 1m from the speaker, or closer to reduce room effects. Adjust recording level to approximately -6 dB below digital peak level and preferably use 24 bit recording.

3. Filter out the test tones in a copy of the original recording leaving the intermodulation products. It is also suggested that frequencies below 90 Hz are also removed leaving the first modulation products intact.

4. Play back the original recording and note the typical recording level on the monitoring meter. Play back the intermodulation products and note the play back level.

The difference between the two indicates the total intermodulation products level.

4. EXAMPLE RESULTS

These are all 48k 24 bit recordings. A complete equipment list is included in the appendix.

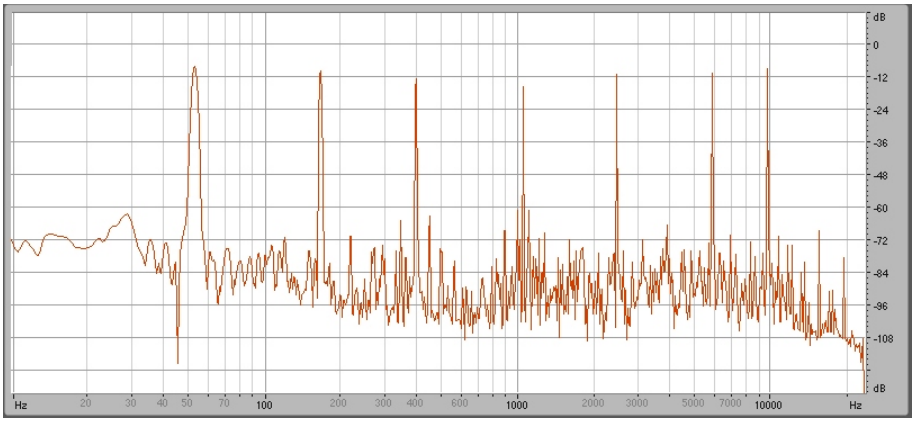


FIG 2.
Spectrum of an original recording of a large high quality 3 way system with a single pole crossover at 400 Hz and 3 pole tweeter crossover at 2500 Hz. Note the unexpected complexity of intermodulation products especially above 1 kHz.

Play back level is -4.5 dB

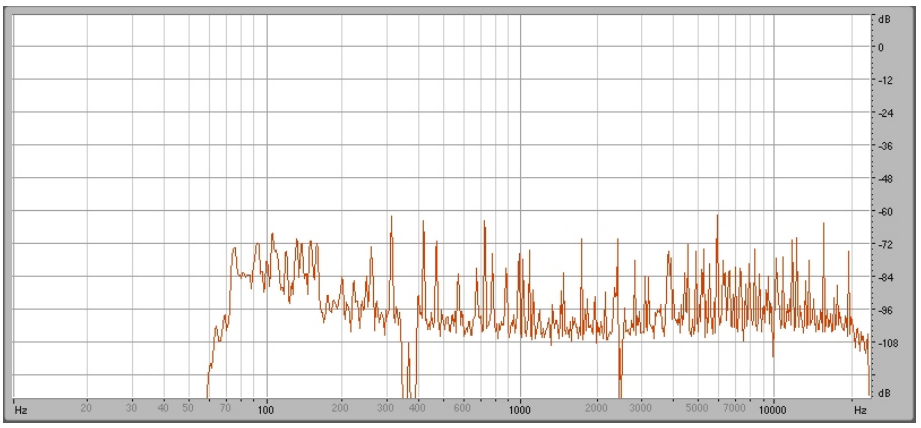


FIG 3.
Processed version of FIG 2.

Play back level is - 54 dB, intermodulation level referenced to FIG 2. is -49.5 dB

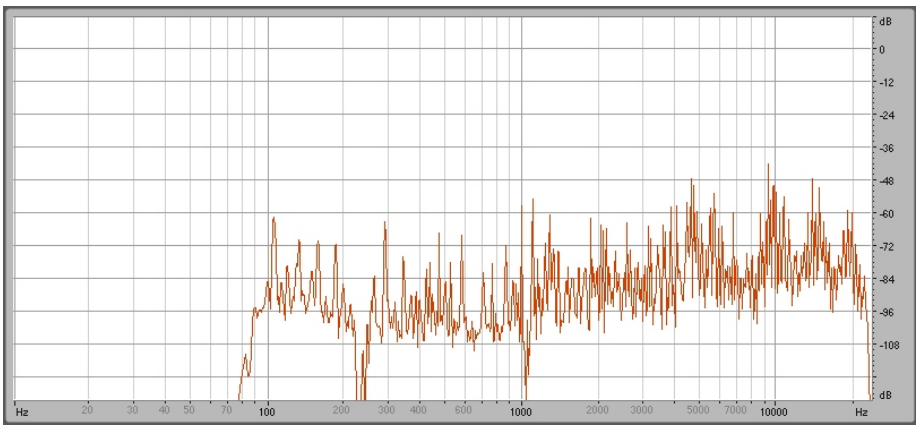


FIG 4.
Intermodulation products for a small 2 way speaker with single pole crossover and small full range driver as mid range and tweeter.

Intermodulation level referenced to the original recording level is -32.5 dB.

4. A DETAILED ANALYSIS OF INTERMODULATION PRODUCTS

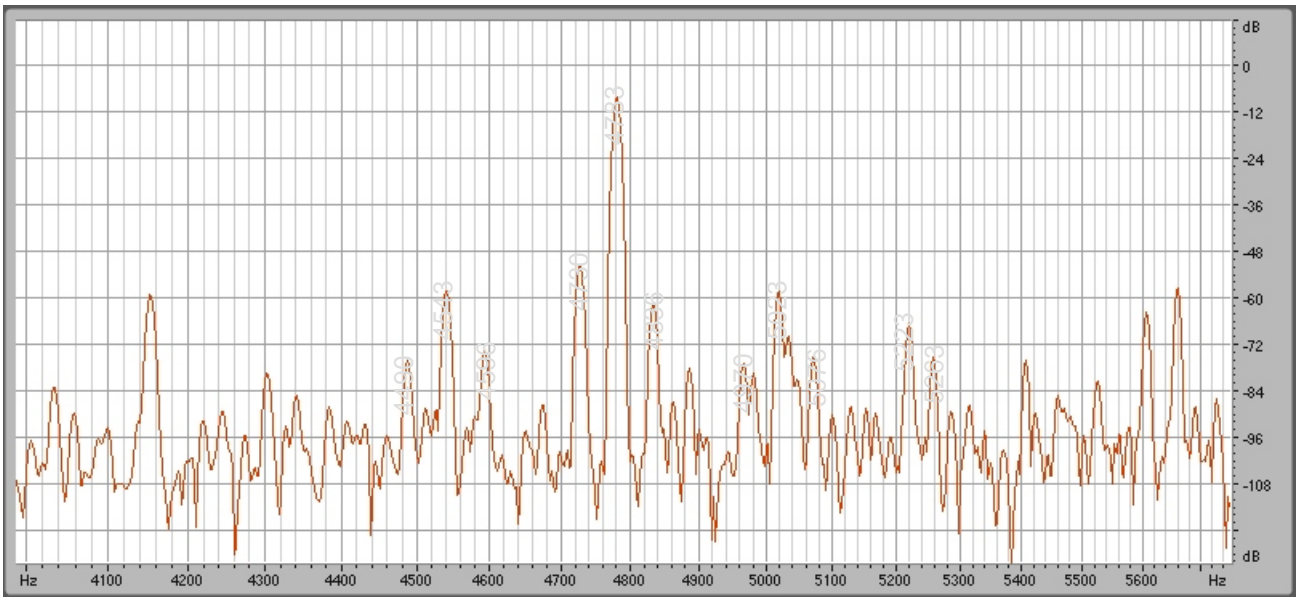


FIG 5. Enlargement of a section of the spectrum in FIG 4.

At this point it is worth examining in greater detail the actual character of the intermodulation products being produced. Referring to FIG 5 :-

1. The group with frequency 4730, 4783 and 4836 Hz are the expected products from the 2 fundamentals at 53 Hz and 4783, typically 40 dB difference.

2. The products at 4543 and 5023 represent products generated by another fundamental i.e. 4783 + - 240 Hz, as expected.

3. However the group at 4543 + - 53 and most other low level products below -72 dB show very high levels of intermodulation products, roughly -15 dB below the fundamental. This is repeated at 5023 + - 53 Hz.

If the speaker were behaving as a system with "linear" distortion characteristics, the intermodulation products at 4543 +-53 Hz and 5023 +-53 Hz should be 40 dB below the level of 4543 and 5023 Hz components.

Clearly this is not the case and all driver types tested so far behave in this way.

5. TESTING INDIVIDUAL DRIVERS

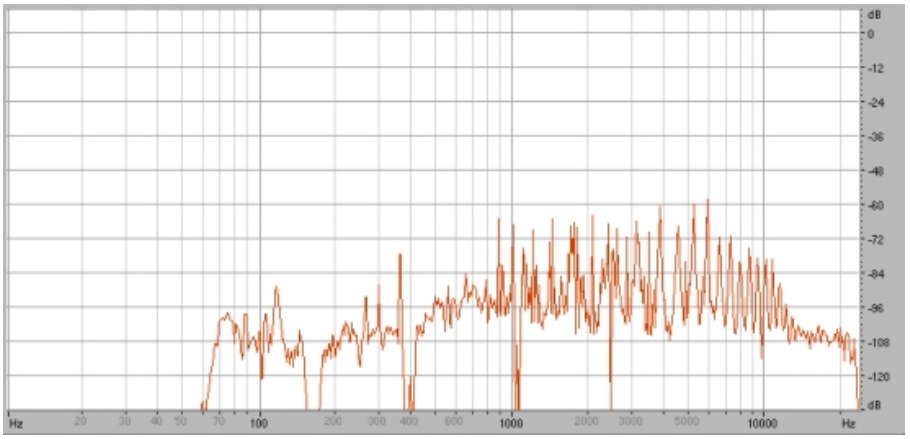
Adobe Audition has a useful range of scientific filters which can be used to simulate the effect of crossovers when testing individual drivers.

Play back the original test signal and note the normal play back level. Apply the required crossover characteristics including any notches, other response shaping and play back the resulting signal. The difference is used to calculate the correct test level when only one driver is being tested.
For example:

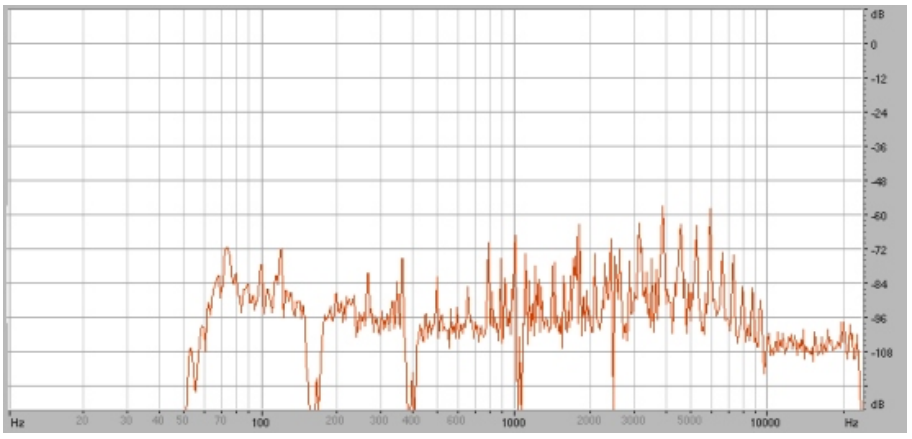
Normal test tone play back level	-4.5dB
Play back level after filtering	-12dB
Difference	7.5 dB
Driver test level	82.5 dBA

It is assumed that 90 dBA is the test level for the complete speaker.

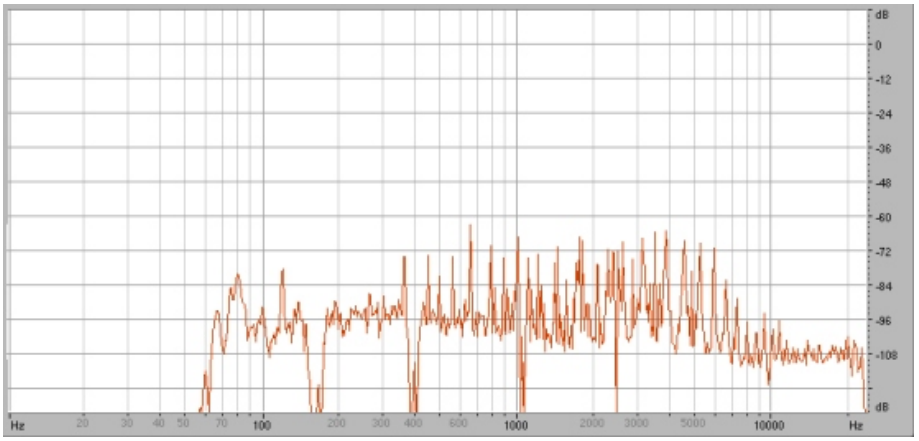
6. EXAMPLE DRIVER TEST RESULTS



High quality 5” mid range driver



High quality 6.5” driver



High quality “8” driver

7. MARSHALL CHOONG INTERMODULATION PERFORMANCE CLASSIFICATION

All speakers and drivers used by MC are evaluated by the use of a 7 tone signal , ranging from 50 Hz to 10 kHz as previously outlined in this article. Each tone is strategically placed to exercise the speaker to the maximum.

Sub woofers use tones at 31, 53 and 89 Hz.

The total intermodulation products are expressed as a proportion of the overall signal level output, at 90dBAlevel, and are given in dB and percentage.

There is good correlation between the perceived performance of quality loudspeakers and the level of intermodulation products (although there are many other secondary parameters) and so we have proposed a banded rating system as follows:

Class E:	-30 to -35 dB	1.7 - 3 %
Class D:	-35 to -40 dB	1.0 - 1.7 %
Class C:	-40 to -45 dB	0.56 - 1.0 %
Class B:	-45 to -50 dB	0.31 - 0.56 %
Class A:	better than -50 dB, < 0.31 %	

As a benchmark, conventional single mid-woofer / tweeter 2 way systems are unlikely to be better than Class D.

In normal domestic and professional listening levels, it is difficult to hear improvements beyond Class B.

The downloads section of the www.marshallchoong.co.uk website have suitable test tones as wav files.

Appendix

1. Prime number list to 4007

2 3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71 73 79 83 89 97 101 103 107 109 113 127 131 137 139 149 151 157 163 167 173 179
181 191 193 197 199 211 223 227 229 233 239 241 251 257 263 269 271 277 281 283 293 307 311 313 317 331 337 347 349 353 359 367
373 379 383 389 397 401 409 419 421 431 433 439 443 449 457 461 463 467 479 487 491 499 503 509 521 523 541 547 557 563 569 571
577 587 593 599 601 607 613 617 619 631 641 643 647 653 659 661 673 677 683 691 701 709 719 727 733 739 743 751 757 761 769 773
787 797 809 811 821 823 827 829 839 853 857 859 863 877 881 883 887 907 911 919 929 937 941 947 953 967 971 977 983 991 997 1009
1013 1019 1021 1031 1033 1039 1049 1051 1061 1063 1069 1087 1091 1093 1097 1103 1109 1117 1123 1129 1151 1153 1163 1171 1181
1187 1193 1201 1213 1217 1223 1229 1231 1237 1249 1259 1277 1279 1283 1289 1291 1297 1301 1303 1307 1319 1321 1327 1361 1367
1373 1381 1399 1409 1423 1427 1429 1433 1439 1447 1451 1453 1459 1471 1481 1483 1487 1489 1493 1499 1511 1523 1531 1543 1549
1553 1559 1567 1571 1579 1583 1597 1601 1607 1609 1613 1619 1621 1627 1637 1657 1663 1667 1669 1693 1697 1699 1709 1721 1723
1733 1741 1747 1753 1759 1777 1783 1787 1789 1801 1811 1823 1831 1847 1861 1867 1871 1873 1877 1879 1889 1901 1907 1913 1931
1933 1949 1951 1973 1979 1987 1993 1997 1999 2003 2011 2017 2027 2029 2039 2053 2063 2069 2081 2083 2087 2089 2099 2111 2113
2129 2131 2137 2141 2143 2153 2161 2179 2203 2207 2213 2221 2237 2239 2243 2251 2267 2269 2273 2281 2287 2293 2297 2309 2311
2333 2339 2341 2347 2351 2357 2371 2377 2381 2383 2389 2393 2399 2411 2417 2423 2437 2441 2447 2459 2467 2473 2477 2503 2521
2531 2539 2543 2549 2551 2557 2579 2591 2593 2609 2617 2621 2633 2647 2657 2659 2663 2671 2677 2683 2687 2689 2693 2699 2707
2711 2713 2719 2729 2731 2741 2749 2753 2767 2777 2789 2791 2797 2801 2803 2819 2833 2837 2843 2851 2857 2861 2879 2887 2897
2903 2909 2917 2927 2939 2953 2957 2963 2969 2971 2999 3001 3011 3019 3023 3037 3041 3049 3061 3067 3079 3083 3089 3109 3119
3121 3137 3163 3167 3169 3181 3187 3191 3203 3209 3217 3221 3229 3251 3253 3257 3259 3271 3299 3301 3307 3313 3319 3323 3329
3331 3343 3347 3359 3361 3371 3373 3389 3391 3407 3413 3433 3449 3457 3461 3463 3467 3469 3491 3499 3511 3517 3527 3529 3533
3539 3541 3547 3557 3559 3571 3581 3583 3593 3607 3613 3617 3623 3631 3637 3643 3659 3671 3673 3677 3691 3697 3701 3709 3719
3727 3733 3739 3761 3767 3769 3779 3793 3797 3803 3821 3823 3833 3847 3851 3853 3863 3877 3881 3889 3907 3911 3917 3919 3923
3929 3931 3943 3947 3967 3989 4001 4003 4007

2. Equipment List

Computer Signal Source:	Fan less noise suppressed PC clone, Windows XP operating system
	Sound Card - RME Hammerfall Multiface II
Computer Recording:	Toshiba Pro Laptop, Windows 2000
	Sound Card - EMU 1616M
Microphone:	Rode NT2A
Audio Software used:	Adobe Audition 1.5