AURAL SENSITIVITY TO PHASE

Though I believe that the effects of phase shift on the waveform and the sound quality of the signal in a monaural channel are of no importance provided that the concomitant time delays stay within the CCIR limits, Mr Lipshitz's letter in the May issue draws attention to one of the many situations where phase shifts are of importance in their effect on sound quality. There are many others.

It has long been the practice of amplifier designers to arrange for the compensation of distortion between the stages in an amplifier by adjusting the operating conditions of successive stages to allow the distortion introduced by one stage to be reduced by the introduction of distortion in the opposite phase by the following stage, the explanation of Mr Lipshitz's results. Similarly, it has been the practice of recording engineers to minimise the peak signal amplitudes and hence the amplitude dependent distortions by appropriate phasing of the signal components. These phase dependent distortion compensating effects make it difficult to measure and specify the amplitude distortion in any good f.m. receiver. The distortion introduced by the best signal generators is of the same order as that introduced by the best current receivers and in consequence the measured overall distortion may vary between almost zero and twice that introduced by the receiver, depending upon the relative phase of the distortion introduced by generator and tuner.

The sound quality of a loudspeaker is subtly dependent upon the relative polarity (phase) of the studio microphone and the listener's loudspeaker but, unless equipment of professional quality is used throughout, the effect is extremely difficult to detect, in part because it is critically dependent upon volume setting.

These are some of the many situations where phase shifts may introduce audible effects but little use can be made of this by the ordinary user, for the distortion cancellation is dependent upon the relative phase and relative amplitude of the recorder-reproducer distortions.

Mr Lipshitz's letter draws attention to a situation where nature anticipated engineers in this practice of distortion cancellation. It has long been known that the negative and positive peaks in ordinary conversation speech are of unequal amplitude, but nature apparently arranged this to compensate for the non-linear stiffness relation of the ear drum. Which effect came first is difficult to identify.

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I suggest that if one regards the ear as a non-linear transducer followed by a set of high-Q tuned circuits each driving a mean amplitude meter, the outputs of which are separately sent to the brain, all arguments are resolved and all observations and tests accounted for, are they not?

As far as the brain is concerned it only receives one parameter for each frequency, namely amplitude of the signal arriving at the resonator; it receives no information concerning phase. However, when a sine wave arrives at the ear, because of non-linearity it produces its own harmonics. If now for example a given amplitude of second harmonic is added to the signal this will be reinforced or reduced in amplitude by the time it reaches the inner ear by the harmonic of the original signal produced by the distortion of the first stage of the ear. In this sense the ear is phase sensitive, as altering the *phase* of the 2nd harmonic fed to the outer ear alters the *amplitude* of the second harmonic received by the inner ear.

If, however, we have a generator in which we can control the amplitude of all the harmonics, after altering the phase of one or more we can usually by altering the amplitude only of these and the other harmonics apparently reproduce the original sound. This is because changes in amplitude of applied signal correct for the changed cancellation reinforcement pattern of the "ear produced" harmonics. In this sense the ear is not phase sensitive.

There are cases when this is not true. If for example the amount of second harmonic applied is of the right amplitude and phase to cancel the ear-produced 2nd harmonic, the amount of this arriving at the inner ear will be nil. If we now alter the phase of the 2nd harmonic from our speaker, cancellation will no longer take place and second harmonic will reach the inner ear. No amount of change of amplitude will cause the amount of second harmonic reaching the inner ear to be reduced to zero.

One cannot answer the question "is the ear sensitive to phase?" by a yes/no answer, only by "the inner ear is insensitive to phase but the outer ear distorts".

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Perhaps I may be allowed to reply to Mr Coleman's letter in the February 1977 issue, even in isolation from the long correspondence on aural phase sensitivity. There is, I