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Author	橋本, 新一郎(Hashimoto, Shinichiro)
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Study of Signaling Frequency Arrangement for Voice Frequency Signaling System

Shin-ichiro HASHIMOTO (橋本新一郎)

1. Introduction

N.T.T. is now developing the push button dialing system as a new telephone service. In the system, voice band frequency signals are sent out from a telephone set as dialing signals, so that there is susceptibility of signal imitation (the phenomena that speech waves imitate the dialing signals). This paper describes an analytical study of signal imitation due to speech wave and estimation of signal imitation rate of the voice band frequency signaling system.

2. Causes of Signal Imitation

The physical conditions on speech wave related to signal imitation are as follows: 1) the amplitude level of speech wave must be above the sensitivity level of signaling receiver, 2) there must be a remarkable peaks in speech spectral envelope which almost coincide with signaling frequencies, 3) the corresponding component to the signaling frequencies must exist in harmonics of fundamental frequency of speech wave, 4) the speech power of exclusive components of the signaling frequencies must be less than a threshold level, 5) the conditions shown above must reasonably keep up for the adequate time.

Considering these conditions and the performance of a signal receiver, we can clearly see that nothing but vowels have possibility of signal imitation. Especially for the 4×4 signaling system with the frequency arrangement which both frequency groups are arranged side by side as shown below, susceptibility of signal imitation is mainly in the formant structure of vowel /a/.

Lower Freq. Group (Hz)	697	770	852	941
Higher Freq. Group (Hz)	1209	1336	1477	1633

3. Estimation of Signal Imitation Rate

For the estimation of the signal imitation rate, it is convenient to take two factors into consideration. The first one is the probability that proper harmonic components of voice fundamental frequency fall into the signaling frequency bandwidth. The second one is the probability of occurrences of formant frequency and the others. This will be given by the residual components which are obtained by removing the effect of fundamental frequency from signal imitations occurred in the single frequ-

ency signaling system. In the dual frequency signaling system, the product of the effects of respective frequencies is taken into consideration.

The estimated relative signal imitation rate of the 4×4 system with the frequency arrangement shown before accords fairly well with that obtained by the field test.

Moreover, it is found that the signal imitation rate of the 4×4 system decreases in the order of 10^{-1} for every frequency interval of half octave, and that the effect of bandwidth on signal imitation rate is proportional to the square of the bandwidth for the dual frequency system.

4. Optimum Frequency Arrangement of Signaling Frequencies

It is important to obtain the optimum frequency arrangement having minimum signal imitation rate. We describe an example of the optimum frequency arrangement in the case of 4×4 signaling system.

In the first place, we arbitrarily give four frequencies as initial ones for the lower frequency group and also a higher frequency, and calculate the sum of the signal imitation rates of the four dual frequency signals by the estimation method described above. Then we continuously move the higher frequency and calculate the corresponding sum of the signal imitation rates. In the second place, the four frequencies obtained are again given as the initial ones, and the same operation is repeated until they converge. An example of the optimum frequency arrangement is as follows:

Lower Freq. Group (Hz)	601	691	759	914
Higher Freq. Group (Hz)	1124	1293	1487	1710

5. The Third Formant Emphasis Method for Suppressing Signal Imitation

As is described above, signal imitation always occurs in vowels. A vowel has an inherent spectral peak around the frequency of 3 kHz called the third formant which is invariant with vowels. By emphasizing this, it is possible to enhance the guard effect of limiter which is equipped in the signaling receiver.

This method improves signal imitation rate in the order of 10 or more times and this is adopted in the signaling receiver of the push button dialing system of N.T.T.