STEPHAN PEUS

Microphones and Transients

THE TRANSMISSION CHARACTERISTICS of microphones during transient investigations are readable directly from the oscilloscope screen or 'scope photo without the necessity of complicated devices for transformation into the frequency domain. Rise and decay time behavior of speech and music is to be found in the 10-100 ms area, while the decay phenomenon in high quality microphones may end in less than 1 ms. That is how such microphones manage to grasp the fine structure of sound. Many microphones constructed solely for linear frequency response add their rise time behavior to the sound being picked up, which then appears as amplitude modulation (a.m.) and gives the microphone its typical "sound." For this reason, the following investigation of the transient behavior of microphones should be taken very seriously, even if this is only one small part of the development of a new microphone.

IMPULSE MEASUREMENTS AND ELECTROACOUSTICS

The transient behavior of electro-acoustic transmission systems has been the subject of discussions for some time. It is at times measured in amplifiers using square waves and is sometimes even published. Publications about transient measurements in microphones are largely limited to the recognition that the transient response, i.e. the result of tests in the time domain after transformation into the frequency domain, contains the transmission functions: transmission factor and transmission angle. The measurement is a very rapid one and one doesn't need an anechoic chamber since the influences of the test room only reach the microphone outside the measurement time. This advantage must be weighed against the expense of a computer which puts out the transformations in graphic form in real time directly from the electrical microphone signal.

Whatever measurement system is used, our purpose is to find out why microphones with nearly identical frequency response curves can have such vastly differing sound quality.

TRANSIENT BEHAVIOR

The frequency response in microphones is measured in their stationary, or static, condition at moderate velocities, while a microphone's "daily bread" is the reproduction of predominantly impulse-type sound occurrences. The first two illustrations show the order of magnitude involved. FIGURE 1 shows the transient behavior of the individual harmonics which make up the syllable "ke." Characteristic for this guttural sound is the impulse rise time pattern and the relatively long decay time of about 120 ms. It is more typical for speech sounds to have a shorter build-up time which is also more gradual, rather than impulse rich. Singly pronounced vowels have the shortest rise time; e.g. "e" only 6 ms. What I am referring to is the time during which there is a significant change in the amplitudes of the harmonics. One can speak of a fully built-up state only for singly pronounced speech sounds intended for research purposes, but never for continuous speech.

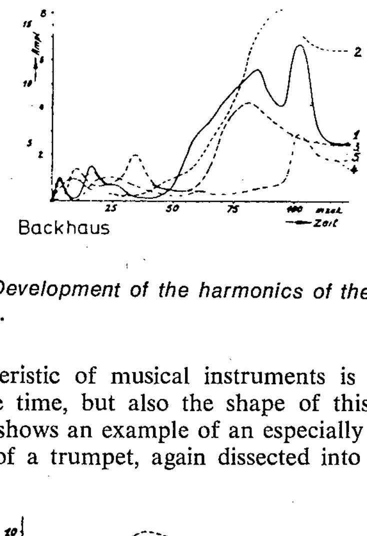

Figure 1. Development of the harmonics of the syllable ke.

Characteristic of musical instruments is not only their longer rise time, but also the shape of this phenomenon. FIGURE 2 shows an example of an especially short transient rise time of a trumpet, again dissected into its harmonics.

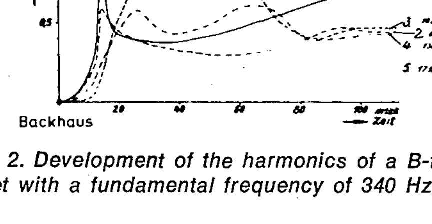

Figure 2. Development of the harmonics of a B-flat trumpet with a fundamental frequency of 340 Hz.

Much shorter times are encountered when the instrument is played since only the change from one *quasi stable* condition to the next is involved.

These two examples with particularly short rise times were selected because in publications, in which the transient behavior study of electro-acoustic devices is recommended, the impression has been given that the impulse content during the rise time period is so short, that a transducer—in this case a microphone—is too slow to be able to transmit the fine impulse structure. This paper is

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Stephan Peus is a German engineer who works for George Neumann GmbH in Berlin. This article appeared in the German publication, radio mentor, *based on a paper given at the Tonmeister Convention in Cologne, Germany in November 1975. It was translated by Stephen Temmer, president of Gotham Audio in New York City.*

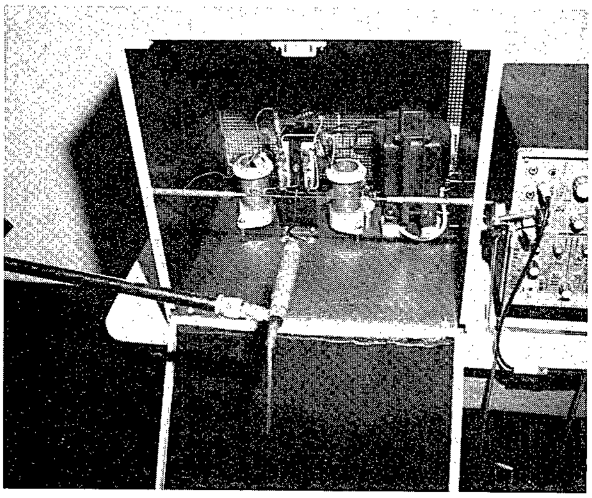

Figure 3. Construction of the spark discharge apparatus.

intended to show that things are actually somewhat different.

THE TEST PULSE

For the measurement of the transient behavior of microphones, one needs a very short, reproduceable signal such as that produced by a pistol shot or the spark discharge of a condenser.

Some years ago, Dr. G. Boré of the Georg Neumann Co. constructed a spark-discharge apparatus in which the power line voltage was raised to 5 kV and after rectification, was used to charge a 600 pF capacitor. A spark gap parallel to this capacitor was adjustable in width to control the energy of discharge, while an r-c network set the repetition rate. The entire apparatus was enclosed in a shielding metal box. To protect the electrodes and to filter out those frequencies far above the threshold of hearing, the cover was lined with felt (shown hinged down in FIGURE 3).

It is not acoustically possible to produce a one-sided pulse such as the square wave used in electrical measurements, since the air together with the discharged capacitor forms a resonant circuit through which the greatly heated and compressed air radiates as a spherical wave, first for a short time at super sonic speed, and then with the well-known differential equations of a sound field. The high degree of attenuation of this resonant circuit resulting from the friction resistance of air only permits one period close to the aperiodic boundary.

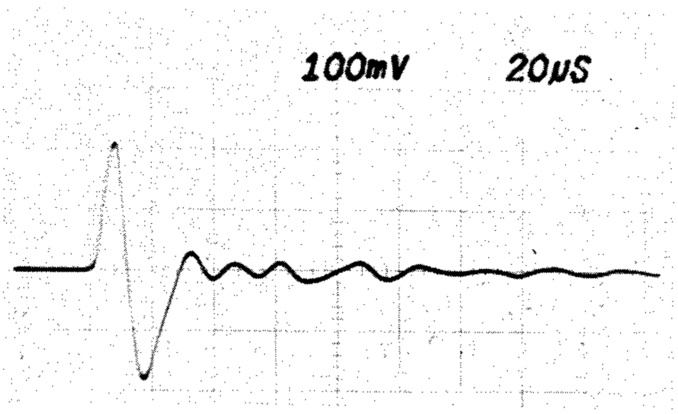

Figure 4. Sound pressure diagram of a spark discharge recorded using a measurement microphone. The time axis is divided into 20µs sections.

The oscilloscope photo in FIGURE 4, made using a very high quality measurement microphone, shows the sound pressure pattern of such a discharge. The slender positive portion, followed by the somewhat flatter and wider negative one resulting from the friction resistance, is typical for such a discharge.

TRANSIENT RESPONSE OF THE MICROPHONE

Every microphone is a transmission system of limited band width. Put in simple terms, it is a low pass filter with an upper boundary frequency and a substantially flat response up to that frequency. This boundary frequency causes a widening of the positive part of the pulse; i.e. the positive part of the transient response. The mean duration and therefore the median pulse width as shown in the illustration, is inversely proportional to twice the boundary frequency.

$$t = \frac{1}{2f_{boundary}}$$

The transition from the pass band to the cut-off area is visible in the response figure as an eigen-oscillation at the boundary frequency. Duration and amplitude of this oscillation are interrelated as follows: a steep cut-off at the upper end of the pass-band results in a short but high damped decay wave, while a flat cut-off produces a longer damped wave with smaller amplitude.

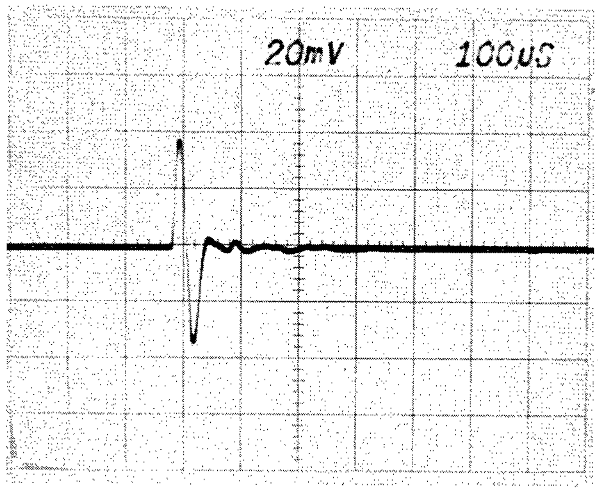

Figure 5. Transient response of a studio quality microphone.

It is, therefore, not to the point to place the boundary frequency as high as possible for the application at hand, but rather to make the transition if it falls within the audio range, such that the relationship of oscillation amplitude and duration of the damped decay wave is optimum for the intended use.

This was visible in the transient response of the measurement microphone where the boundary frequency of 60 kHz is noticeable both in the particular pulse width of about 8 µs and the damped decay wave at this frequency.

CONDENSER MICROPHONES

FIGURE 5 shows the transient response of a studio quality microphone which reproduces the pulse correctly within its physical limitations. The boundary frequency of over 20 kHz shows itself again in the corresponding width of the pulse, but almost not at all in the eigen-oscillation at that frequency, due to the proper choice of slope in the transition range. This microphone produces no sound coloration whatsoever.

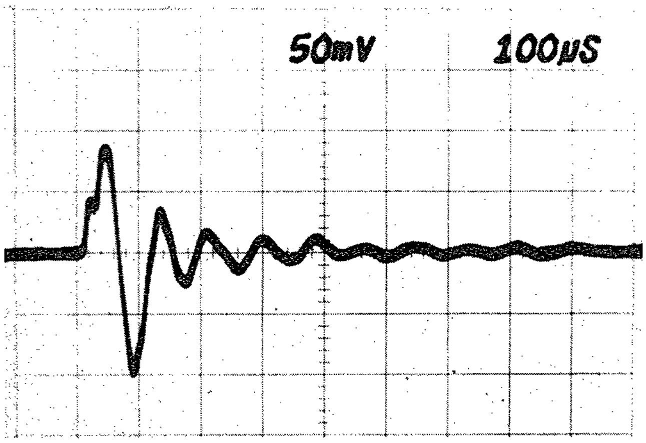

Figure 10. Transient response diagram for the frequency response in Fig. 9.

By contrast there are microphones which have built into them oscillation-prone components, such as small chambers accessible to the sound to boost a certain frequency for the sake of increased brilliance or to expand a frequency response of insufficient width.

FIGURE 6, for example, shows a response curve with a boost of only 2 dB at about 8 kHz and an early cut-off. In FIGURE 7, we see the transient response showing these properties in the width of the pulse and the resonance of the built-in chamber at about 8 kHz.

This type of microphone, therefore, boosts frequencies in the 8 kHz range by some 2 dB and additionally may excite this oscillation-prone system at its resonance. This leads to an intensification of the effect. These response-boosting means must be used with great care, since acoustic resonators are very narrow-band in nature and are readily recognized by experienced listeners.

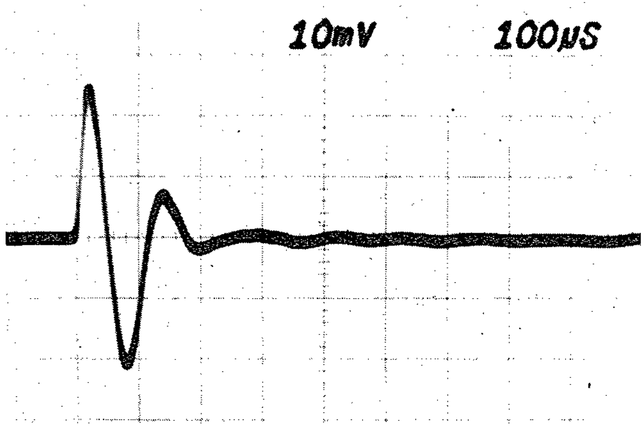

Figure 7. Transient response diagram for the frequency response in Fig. 6.

FIGURE 8 shows a condenser microphone which has been constructed solely to produce a "pretty" response curve and proves that the choice of a condenser microphone transducer with good frequency response does not necessarily guaranty a good sounding microphone.

At this point it is important to point out one of the properties of the human ear as a receiver—the so-called *psychological rise time.* Investigations have shown that two signals which have differing transient response characteristics will only then be judged by the ear as having different sound quality if their rise time is longer than 250 μs.

This condition was not met by the microphone with the resonant circuit (FIGURE 7), so that single pulses re-

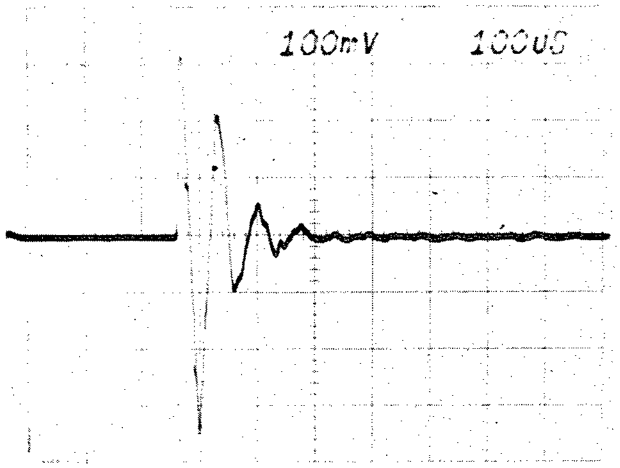

Figure 8. Transient response of a condenser microphone designed for a "beautiful" frequency response.

corded with it will likely not ring at the 8 kHz frequency. However, it should be noted that this transducer will be constantly excited by the impulse character of speech and music, which will result in a quasi-stationary oscillation at this frequency, undoubtedly leading to coloration of the resulting sound. This is reputed to be desirable at times.

Even if no resonant systems with a frequency in the audible range are built into a microphone, the membrane with its mass and the stiffness of its suspension forms an oscillation-prone system in which the not-to-be-neglected vibrating air mass must be added to that of the membrane.

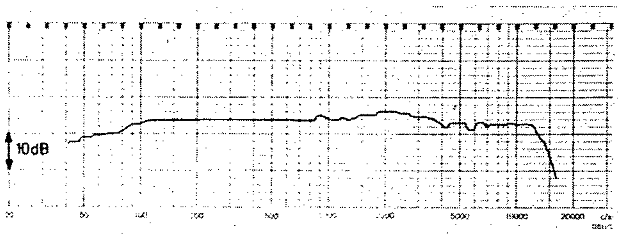

Figure 9. Frequency response of a high quality dynamic studio microphone.

DYNAMIC MICROPHONES

Both gradient condenser microphones and dynamic microphones generally have a membrane self-resonance within the audible range in common. This resonance, depending on the type of microphone, is damped either in a frequency independent (friction controlled), or frequency dependent (mass controlled) way. Due to their transducer principle, dynamic microphones usually have larger membranes with correspondingly greater mass, and must therefore have more compliant suspension to achieve the resonant frequency. As a result, such systems have a much longer decay than microphones with smaller effective membrane mass, and with it less compliant suspensions, such

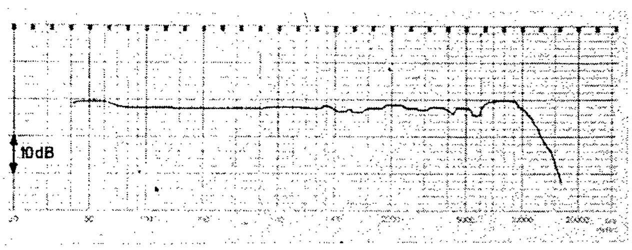

Figure 6. Frequency response of a cardioid condenser microphone with a 16 mm membrane diameter.

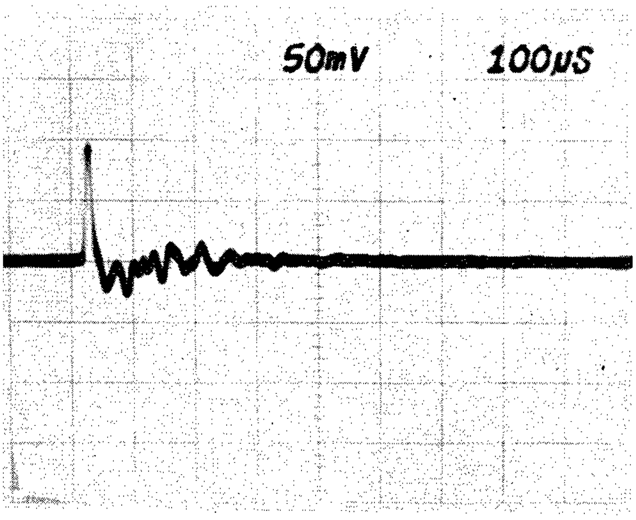

Figure 11. Transient response of a double ribbon microphone.

as condenser or ribbon microphones. Two illustrations show the effect of this on the transient response of these microphone types: FIGURE 9 shows the frequency response of a dynamic studio quality microphone, which is linear throughout the pass band but shows the typical steep cut-off at 13 kHz.

In the corresponding transient diagram, FIGURE 10, this boundary frequency is readily recognizable in the pulse width and the slow decay of the damped oscillation. There is a 20 µs pulse in the leading flank which cannot be explained here but which will not be of interest due to its very short duration.

RIBBON MICROPHONE

FIGURE 11, our last example, shows the transient response of a double ribbon microphone. The small mass is reflected both in the pulse width and the eigen-oscillation at a very high frequency. One can recognize 25 kHz and 50 kHz, the latter being confirmed as the boundary frequency from the pulse width. FIGURE 10, on the other hand, clearly shows that the response ends at about 10 kHz, so that one must assume that only a portion of the double ribbon is modulated at this high velocity and actually misrepresents such a high boundary frequency.

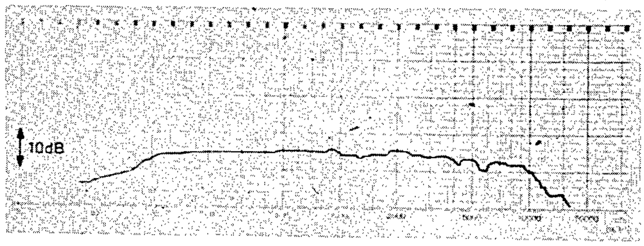

Figure 12. Frequency response of the double ribbon microphone.

There are several transmission characteristics, therefore, which may be read directly off the oscilloscope screen without the necessity of transforming into the frequency domain. The fine structure of the signal is visible and recognizable, and one can see how many a microphone built solely for good frequency response, gets its characteristic "sound." ■