Experiment shows, that group velocities for ultra low frequency voltage signals in short coaxial cables can be significantly faster than light

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Abstract

Recently, during the experimental testing of some basic assumptions in physics, it became apparent that ULF voltage signals in coaxial cables with a length of only a few hundred meters exhibit very anomalous behavior. In particular, they seem to propagate significantly faster than light. The basic idea of the experiment described in this article was to determine with a dual-channel oscilloscope the delay that occurs when the first input is connected to a signal source via a short coaxial cable and the second input to the same signal source via a long coaxial cable. It was observed that the delay between the two channels does not only decrease as expected with decreasing cable length, but that when falling below a certain frequency the delay becomes so small that the associated phase velocity exceeds the speed of light. It is also remarkable that even band-limited signals such as music tracks or speech can be transmitted several times faster as with the speed of light without noticeable loss of quality. Should the observations described here be confirmed, this would be proof that information can be transmitted faster than light.

1. Introduction

In today's information technology, hardly any audio signals are transmitted analog and in the baseband, as this is accompanied by numerous disadvantages such as high sensitivity to noise and low information density. Even the transmission of information by means of electrical voltages is on the decline, since information can be transmitted much better optically over long distances.

In the past, however, the transmission of information in telephone cables played a key role in communications engineering and there even arose a separate discipline dealing with the transmission properties of electrical cables. This sub-discipline of electrical engineering, known as the transmission line theory, is based on the telegrapher's equations [1, p. 307 et seq]. It is primarily concerned with the question of how signals propagate in transmission lines whose length is about the order of the wavelength of the transmitted signals or longer. However, the ULF signals studied in this article have a wavelength of 100 to 1000 kilometers, but the cables examined have a maximum length of only 500 meters. It is obvious that transmission line theory could possibly provide incorrect results here.

It turns out that the transmission line theory fails indeed for this case. Nevertheless, it is quite astonishing that there is not a single experiment that measures the phase velocities of ULF signals in transmission lines that are very short compared to the wavelength. The author can only assume that this omission can be explained by the lack of technical relevance, for low frequencies unfavorable measurement methods such as time-domain reflectometry [2], the dominance of the special theory of relativity, and the belief that someone else has already performed such measurements.

In fact, the question of how fast slowly oscillating electrical signals propagate is of great theoretical interest. If one permits the idea that the vacuum is a dielectric medium, so the propagation velocity would be a simple material constant. At the same time, however, it would be unclear how fast the actual electrical force propagates. For example, sound waves in the air are also much slower than the force that interacts between the air molecules.

In order to clarify this question, the author posed the question at which frequency a very slowly oscillating electric force becomes an electromagnetic wave and whether the disturbing influences of the dielectric medium can be neglected for a sufficiently low frequency. As a logical consequence of these considerations, he performed the experiment described below, whereby he attached great importance to simplicity and reproducibility.

2. Experimental setup

2.1. Hardware

For the experiment, a *PicoScope 2204A*, BNC connection cables and connectors, a *Debian* Linux PC, several hundred meters of coaxial cable (RG6 PVC, 135 dB, characteristic impedance: 75 Ohm, 0.12 Ω/m, 50 pF/m) and a software were used, which source code can be downloaded from *Github* [3]. The basic idea of the experiment is to connect one input of the oscilloscope with a short cable and the other input with a long cable with the same signal source and to measure the delay (figure 1). Since the *PicoScope 2204A* has an integrated signal generator, the oscilloscope itself can be used as signal source for different frequencies. A further advantage of the *PicoScope 2204A* is that it can sample both inputs in parallel at 1 MHz and transfer the samples to the connected PC via USB. This enables the PC

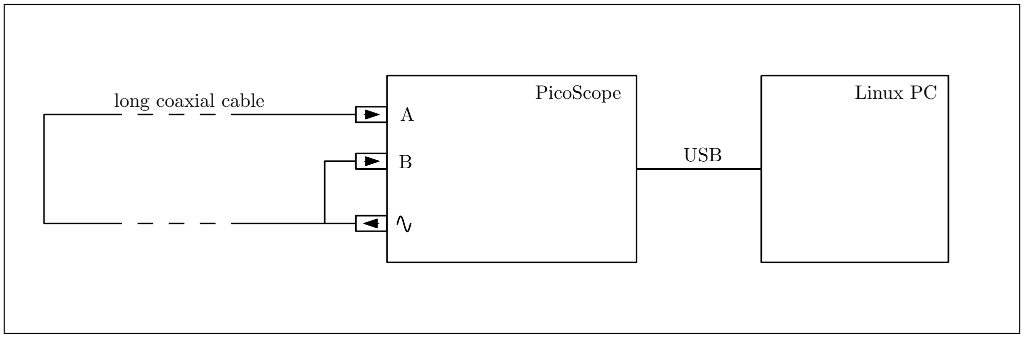

Figure 1: Experimental setup

to store the recorded signals and to perform an analysis.

2.2. Software

For the experiment, a software was developed which configures the PicoScope in such a way that it outputs a sinus signal at the output of the function generator for 65 seconds, simultaneously samples both inputs with 1 MHz and transmits the data to the PC. The PC stores the received sample streams into a stereo WAVE file. This has the advantage that the recorded signals can be easily opened and analyzed with audio tools such as *Audacity*.

To determine the delay, the software calculates the cross correlation between the two channels of the stereo WAVE file. The delays are usually below of one microsecond, which means below the time resolution of the sampling. Nevertheless, it is possible to detect even very small delays, since the sampling rate is about twenty times higher than the highest signal frequency and the signal is therefore strongly oversampled.

Due to this oversampling, the calculated correlation function is also a strongly oversampled sequence, which makes it possible to interpolate the calculated correlation function and determine the position of the global maximum of the interpolated correlation function. Cubic splines are used as the interpolation method, although this method is sensitive to noise. In comparison to ideal interpolation using the Shannon theorem, cubic splines have the advantage that the global maximum can be found in an analytic way. The low noise of the measured delays and the good reproducibility of the measurement results show that the use of splines instead of an ideal interpolation does not cause any disadvantages.

The software also provides a method to remove all frequencies beyond a cut-off frequency, for example 100 kHz. It uses an STFT filter for this purpose. The use of the filter is a way to reduce high frequency noise, which can have a negative effect on the calculation.

3. Findings

3.1. Calibration

In order to determine whether a systematic phase error exists between the two inputs of the oscilloscope, both inputs were connected to the signal generator via measuring cables of exactly the same length. A low-frequency sinus signal was then generated several times for one minute for each frequency and the delay was determined using the evaluation software. The figure 2 shows that the oscilloscope has a small frequency-dependent phase error and that signals at input B are measured with a slight delay.

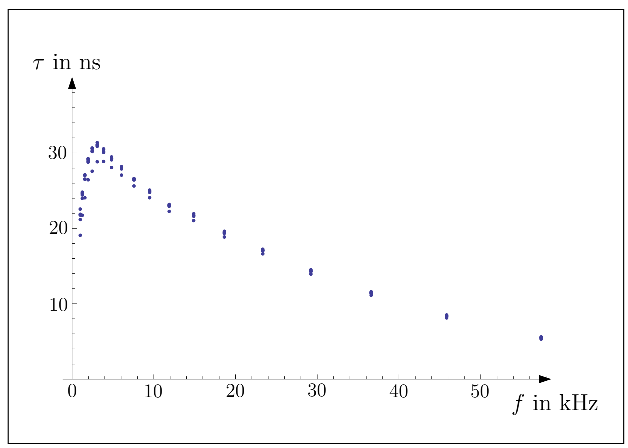

Figure 2: Measured phase error between inputs A and B of the oscilloscope depending on the signal frequency f

3.2. Phase velocities

In the first stage of the experiment, the phase velocities were determined as a function of frequency and conductor length. For this purpose, sinus signals with the frequencies 1000, 1252, 1568, 1964, 2460, 3080, 3857, 4831, 6050, 7576, 9488, 11882, 14880, 18634, 23336, 29224, 36598, 45833 and 57397 Hz and cable length differences of 500, 300, 200 and 100 meters were examined. For each configuration, several measurements were performed and repeated at different times. Furthermore, the longer cable was sometimes at the first input of the oscilloscope and sometimes at the second input. The measured delays τ are shown in Figure 3.

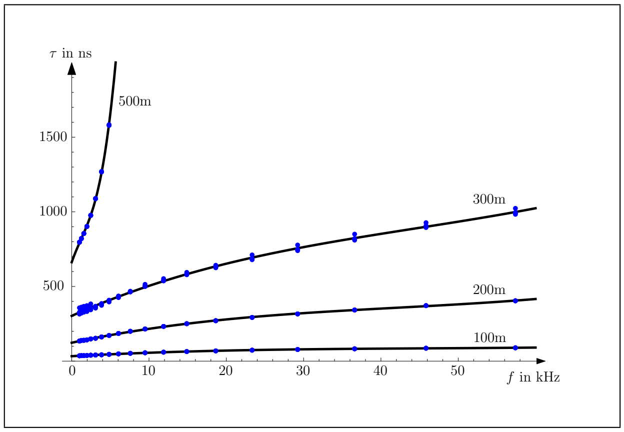

Figure 3: Measured signal delays τ between the two channels for sine waves as a function of cable length and signal frequency f

The scattering observed during the measurements was relatively small. Furthermore, the measured delays were symmetrical except for the systematic phase error of the oscilloscope. The figure 4 shows the phase velocities v_p resulting from the measured delays. As can be seen, these are far beyond the speed of light for frequencies in the audio range.

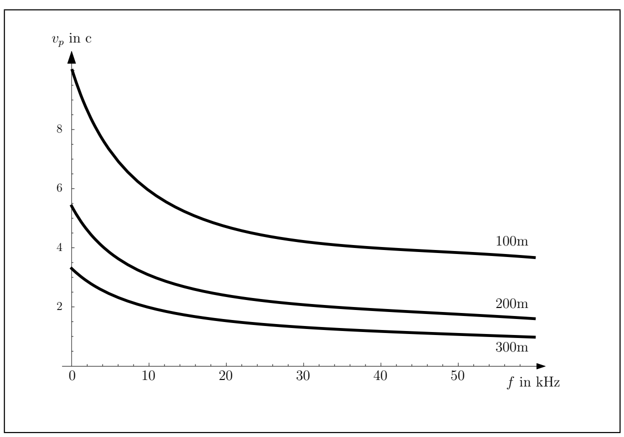

Figure 4: Phase velocities v_p as a function of cable length and signal frequency f

It should be noted that over-fast phase velocities with a cable length of 500 meters only occur at frequencies below of about 5 kHz. For frequencies beyond this, the electromagnetic wave effects seem to dominate more and more.

3.3. Signal propagation time of a music track as a function of the cable length

In order to study whether the very high phase velocities for ULF and VLF signals also lead to very high transmission speeds for general, but band-limited signals, a soundtrack, namely *An End, Once and For All* from the computer game *Mass Effect 3*, was transmitted over cables with different lengths. For this purpose, instead of the signal generator, the right loudspeaker output of a hifi system was connected with the oscilloscope in two different ways, namely via a long coaxial cable and directly.

The cable lengths were varied and the delays were determined. Furthermore, the input at the oscilloscope was varied again, i.e. the long cable was sometimes at input A and sometimes at input B. The measured delays showed little scattering, were reproducible and symmetrical with respect to the oscilloscope input. The quality of the transmitted music was similar on both channels after the transmission and a difference was not audible. Table 1 summarizes the measurement results.

cable length	needed time	velocity
100 m	39.6 ns	8.4 c
200 m	141.0 ns	4.7 c
300 m	319.2 ns	3.1 c
500 m	944.5 ns	1.8 c

Table 1: Measured propagation velocities of the audio signal

It should be noted that the author has also visually checked the samples of both channels. Only a 500 meter cable showed a shift of one sample between the channels in the audio data. Since this corresponds to a time of 1000 ns at a sampling rate of 1 MHz, this is quite consistent with the results in table 1.

4. Summary and final remarks

The determination of the presented measurement data was carried out very carefully and systematically. At the beginning, the author was deeply suspicious of his own measurement results. In the meantime, however, he is of the opinion that measurement or interpretation errors are no longer very likely to explain the results. Instead, the observed results suggest that low-frequency voltage signals in short copper cables do indeed propagate faster than light. However, this only applies if the cable resistances are sufficiently small. The exact dependency from the resistance is still unknown and it should be investigated in an appropriately equipped laboratory how ULF voltage signals propagate in superconductors.

Moreover, the author hopes that the experiment will be repeated several times and will be thoroughly questioned. For this purpose the used software can be downloaded as source code on *Github*. Perhaps an explanation can be found that is consistent with the basic assumptions of contemporary physics.

And last but not least, the author encourages the scientific community to develop new simple experiments which test the seemingly trivial foundations and not to rely on what had to be taken for granted a century ago due to a lack of measuring means.

References

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