Question:

Why and how it was decided that 44,100Hz sampling rate can reproduce sound realistically enough to fool the human ear? Can I get realistic results if I record sound using 44,100Hz sampling rate?

Answer:

Sound waves are successive or fluctuating levels of pressure, propagated in some elastic medium, usually air. These fluctuations consist of a series of compressions and rarefactions of the molecules of the medium or in other terms a rapid succession of raisings and lowerings of air pressure from its static norm.

The approximate range of human capability of hearing sound waves fluctuate at some rate of frequency between 20 and 20,000 times/cycles each second.
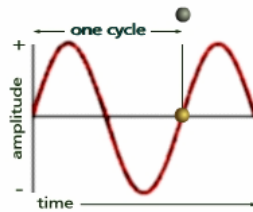
Sound wave cycle

Since 20,000 cycles/sec frequency is the upper limits of what humans can hear, it was realized that the audio must be sampled at 40,000Hz cycles/sec or higher. This is twice the frequency the human ear can hear. The reason of using such a sampling rate (or higher) is to reduce entropy[1], and hence ensuring a more accurate reproduction of the original analogue waveform.

Sound reproduction, as in any other closed systems, has to deal with entropy. In a sound reproduction situation, the sound wave goes through several transductions, such as electrical, magnetic, and mechanical. This process creates entropy; in the case of sound it translates to noise.

Consequently, and to reduce noise the digital audio is typically sampled at 44.1 kHz (for CD recordings) or 48 kHz (for professional audio applications) to reduce entropy. Higher sample rates for professional recording are becoming popular. These include 88.2 kHz, 96 kHz, and 192 kHz. On the other hand, speech signals for telephony are only sampled at 8 kHz.

To sum, the higher the sampling rate is the further away entropy is pushed beyond the capabilities of human ear to detect it. The 44.1 KHz sampling rate was decided to be a good balance between storage limitations and quality requirements.

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[1] Entropy: A measure of the disorder or randomness in a closed system.

Resources:

http://www.sfu.ca/sca/Manuals/ZAAPf/s/sound_waves.html
http://www.recipeland.com/encyclopaedia/index.php/Sound_reproduction
http://www.disctronics.co.uk/technology/cdaudio/cdaud_digaudio.htm