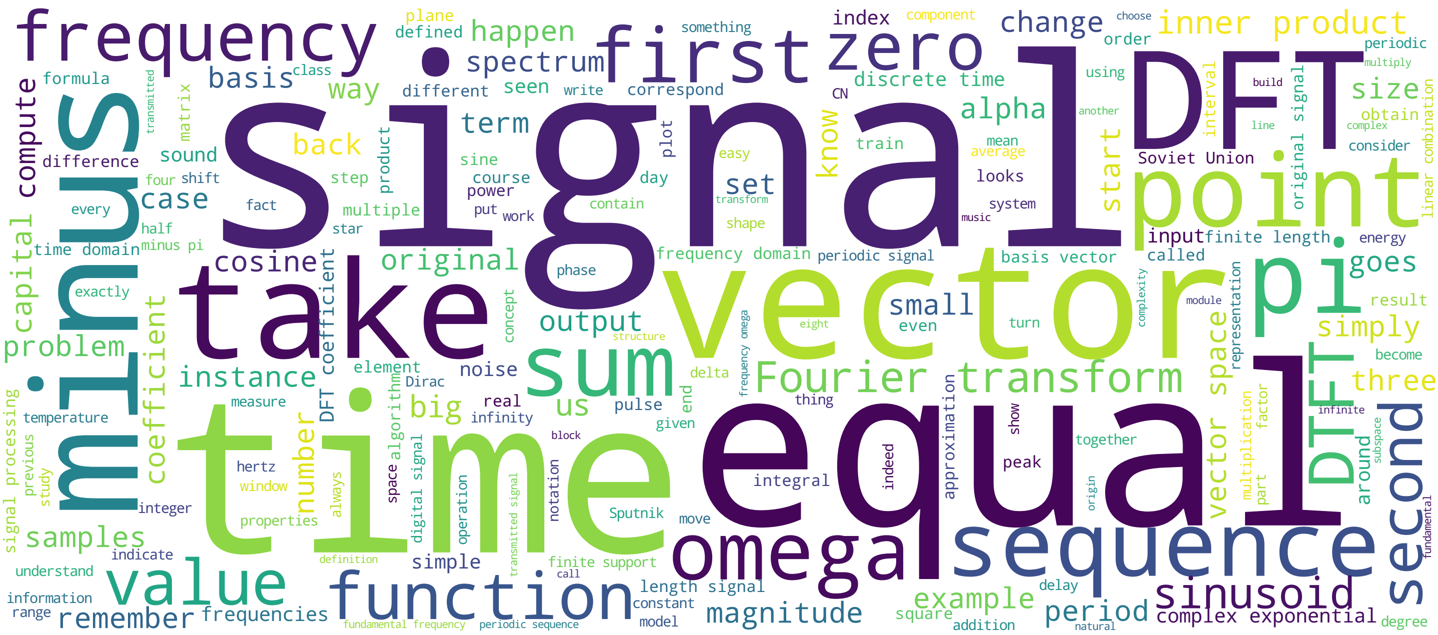
Digital Signal Processing

Signal of the Day: The First Man-Made Signal From Outer Space



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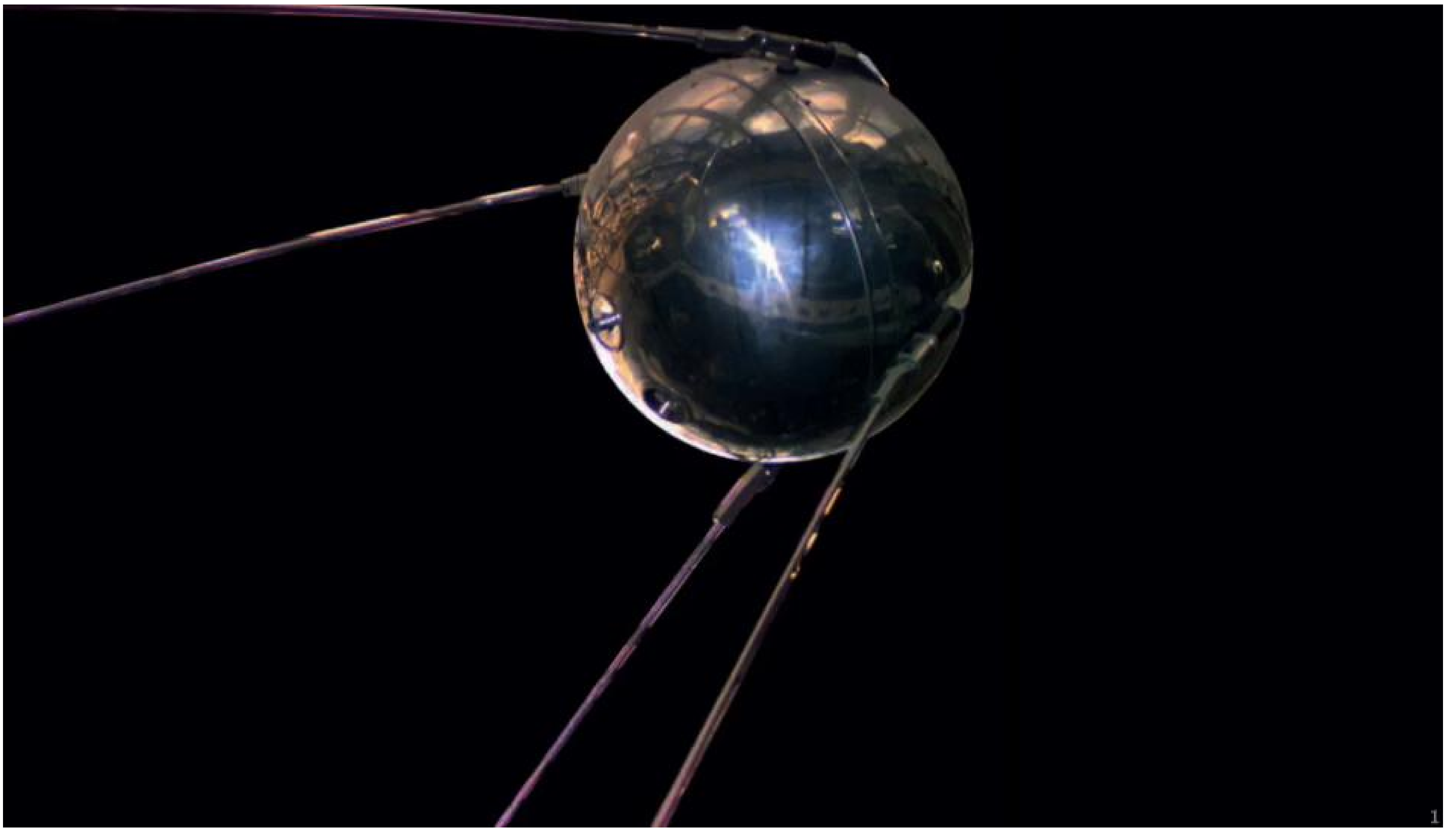


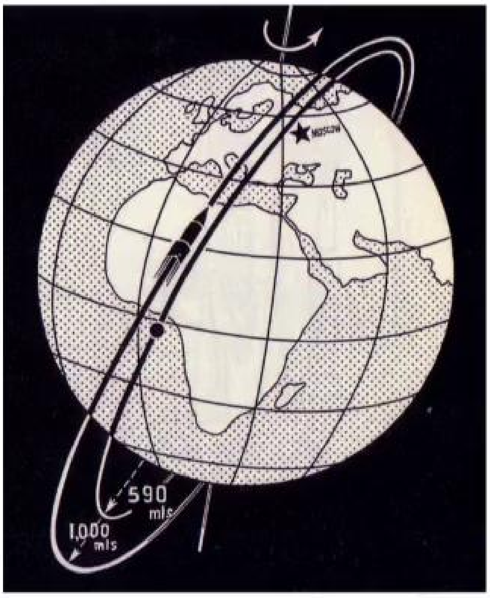
The first manmade signal from outer space. Sputnik was the first artificial Earth satellite launched by the Soviet Union on October 4th, 1957. Its main spherical body was surrounded by four external radio antennas which transmitted a signal. This signal is thus the first manmade signal sent from outer space. Although Sputnik was in orbit for three months, its signal only lasted for 22 days at which point it ran out of power.

Notes

Summary

0m 00s

The Signal



play stop

2

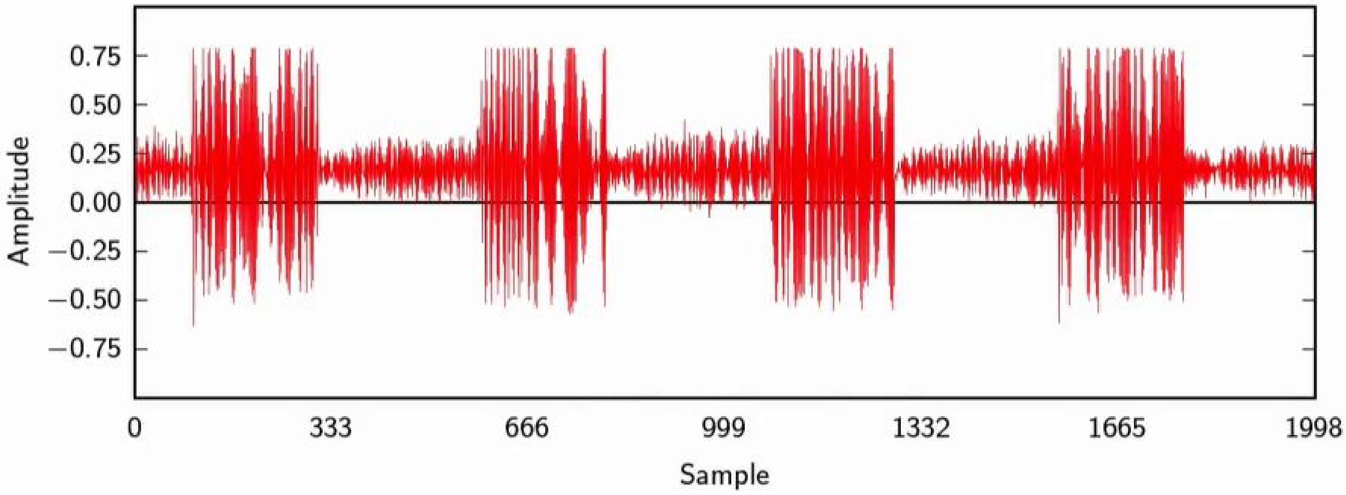
Amateur radio operators could detect the signal all over the world. Just imagine, you're one of these radio operators back in 1957, all excited to participate in this historic moment, and let us listen to the received signal. The transmitted signal was just a sequence of beeps, which is what we can in fact hear. We also perceive a large amount of background noise, which is due both to the type of equipment of the day, but also because of the background noise that is natural in such recordings.

Notes

Summary

0m 35s

Let's Have a Look



3

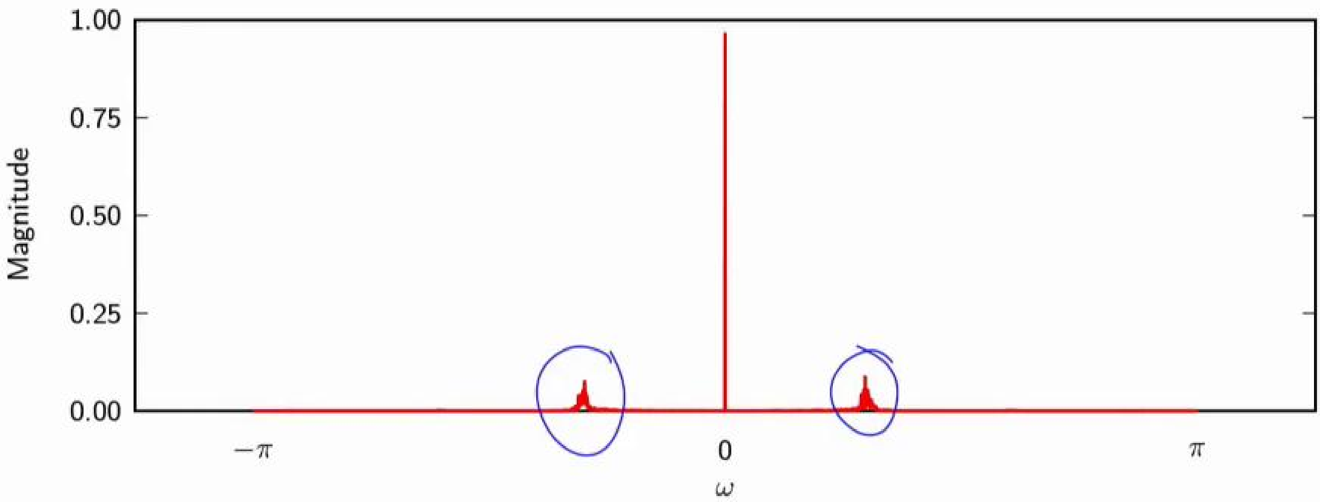
Let us have a look at the signal. This plot shows only two seconds of the audio recording. We clearly see the beep as well as the noise contained in the signal between the beeps.

Notes

Summary

1m 25s

Another point of view: DFT



4

In class, we also studied another tool, namely the Fourier transform, which allows representing a signal in terms of the different frequency components it contains. It is just a change of point of view, and the operation can be inverted to recover exactly the original signal. We are plotting the magnitude of the Fourier transform of the signal transmitted by Sputnik. There is a large component at ω is equal to 0, the origin, which corresponds to the constant component of the signal. This is the so-called DC component in electronics. We also observe two smaller peaks which correspond to the frequency of the transmitted beeps. Fourier representations are defined on the interval -π to +π and are 2π periodic. However, it might not be clear how the concept of discrete frequency relates to the more intuitive one of continuous frequency. The latter are easy to understand from our daily life and expressed in 1/secs or hertz.

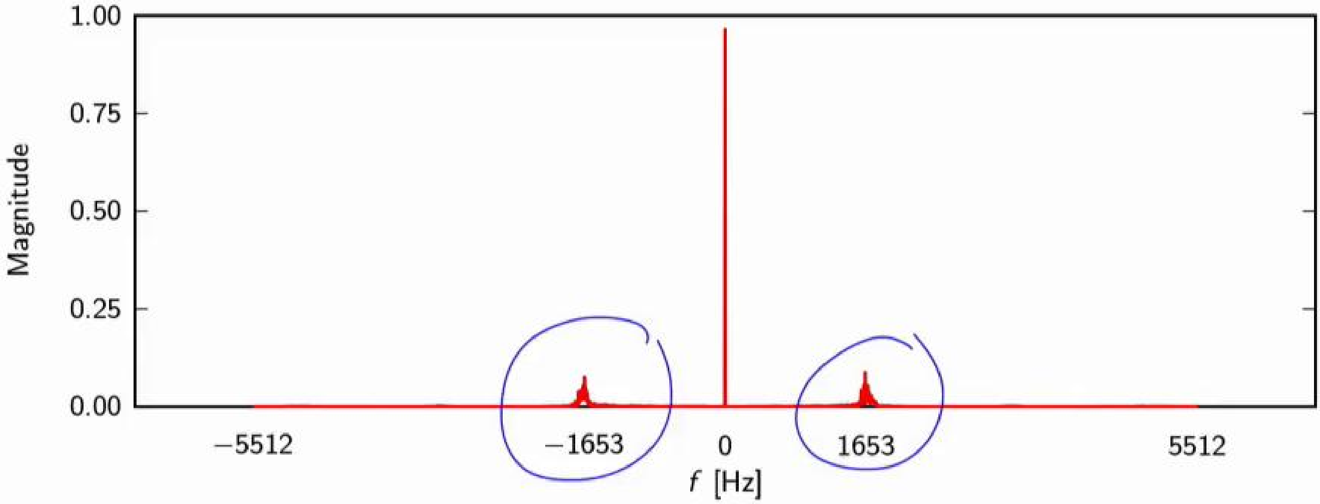
Notes

Summary

1m 37s

Another point of view: DFT

$$\boxed{f = \frac{\omega f_s}{2\pi}}$$



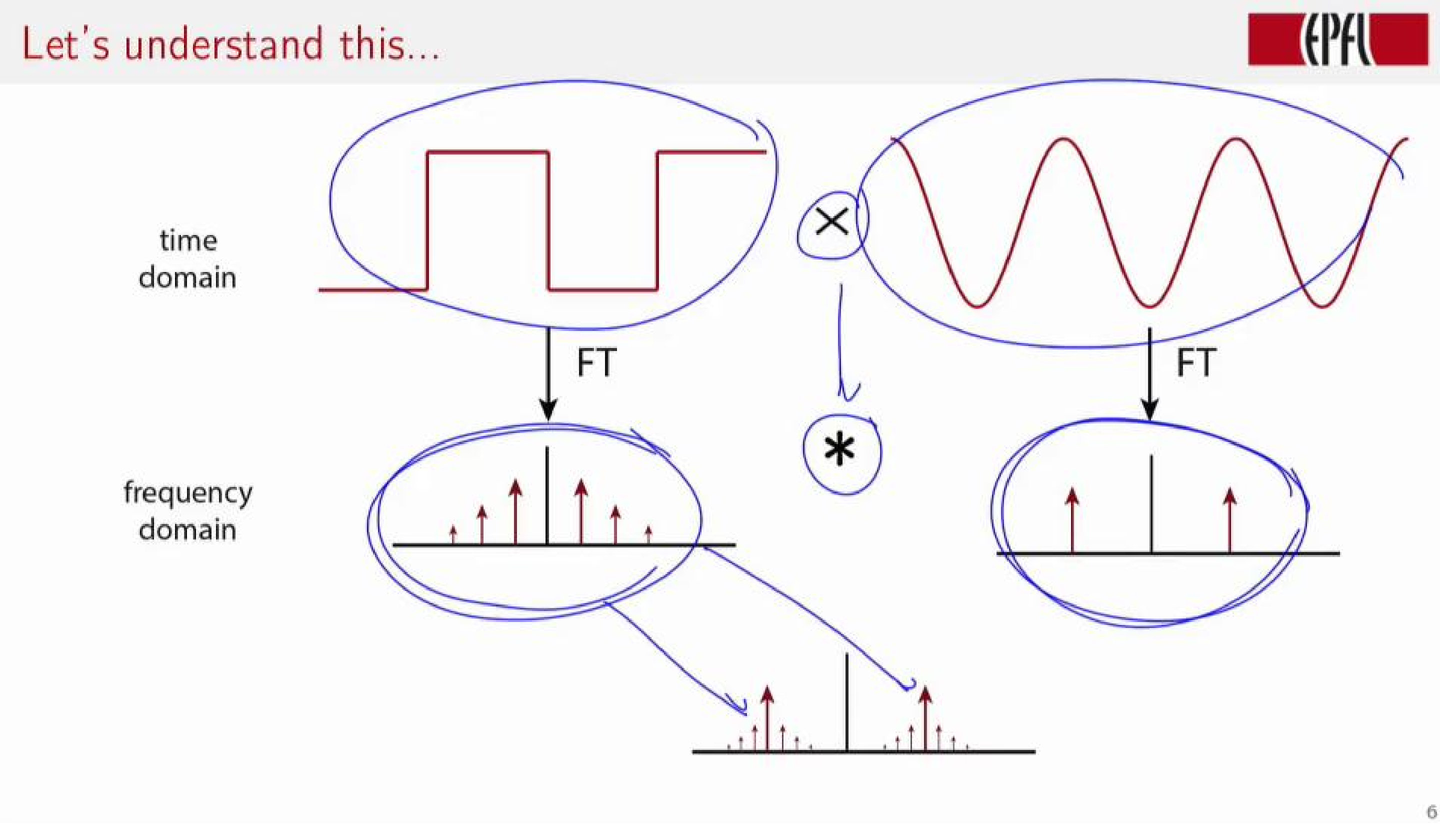
5

The continuous frequency f and the discrete frequency omega are related by the following formula: where fs is the sampling rate of the signal, that is the frequency at which we measure the signal. This link and the explanation of this formula will be made clear when we study the chapter on sampling and interpolation. We see that the two peaks appear now at +/-1653 hertz.

Notes

Summary

2m 45s



Let us further study what happens when moving from time to frequency domain. In the time domain, let us simplify our signal and model as a product between a train of square pulses and a sinusoid. The square pulse here turns on and off a sinusoid here by simply multiplying the two signals. Let us study what happens in the frequency domain. The train of pulses is a periodic signal whose DFT consists of deltas placed at the multiples of the fundamental frequency at which the pulse oscillates. The DFT of the sinusoid consists of two deltas placed at the positive and negative digital frequency of the sinusoid. Moreover, as seen in the lecture when we studied the properties of the Fourier transform, the product in time domain correspond to a convolution in frequency domain. Thus, we obtain a DFT that looks like the figure at the bottom. So we convolve this spectrum with this one, and this replicates the little spectrum here at the two locations of the Diracs given by the sinusoid. How does this compare with our original signal? First, notice that the frequency of the sinusoid is much higher than the frequency of the train of pulses. The Diracs of the pulses are going to be very small and masked by the overall noise. The two main peaks at 1663 hertz correspond to the Dirac of the sinusoid.

Notes

Summary

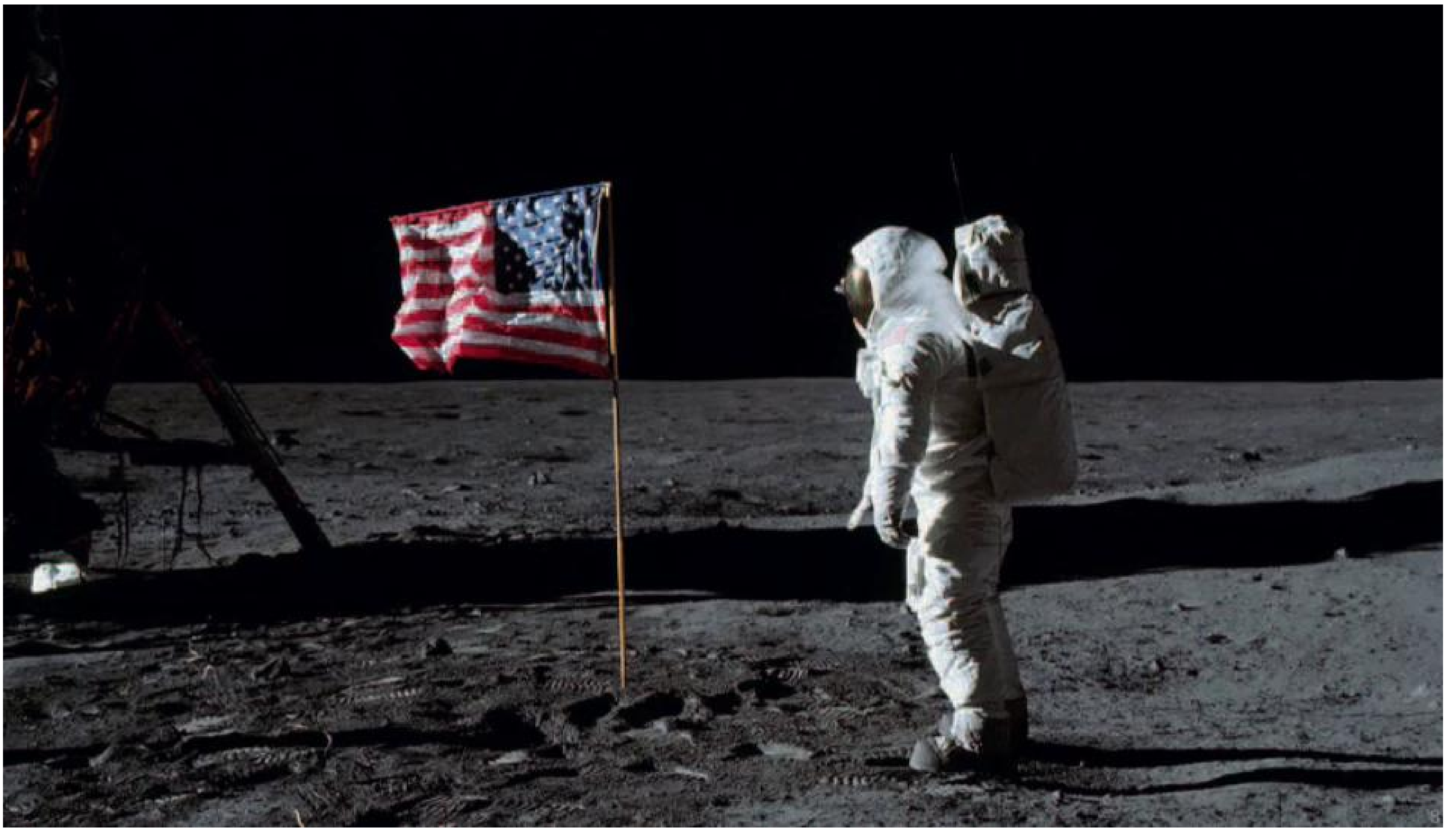
3m 19s

The transmitted signal did not contain any particular information, so what makes it such an important scientific milestone? Its first impact lies in the fact that it demonstrated the possibility of satellite communications. It would take another 10 years to become reality whereas it is ubiquitous today.

Notes

Summary

5m 01s



The successful launch of Sputnik also arose at a time of intense tension between the Soviet Union and the USA, called the Cold War. With the successful launch of Sputnik, the Soviet Union clearly demonstrated its scientific advance, which led to a crisis in the US called the Sputnik Crisis. The US government started intensely funding research and education programs in engineering and sciences to catch up with the Soviet Union. This program culminated 10 years later with the Apollo program and the US being the first country to land on the Moon.

Notes

Summary

5m 21s