

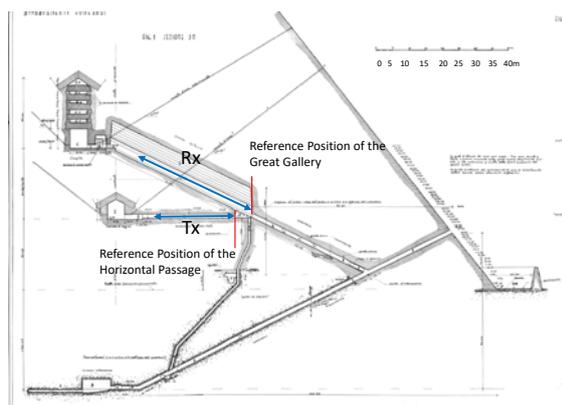
## Electromagnetic Wave Propagation inside the Great Pyramid

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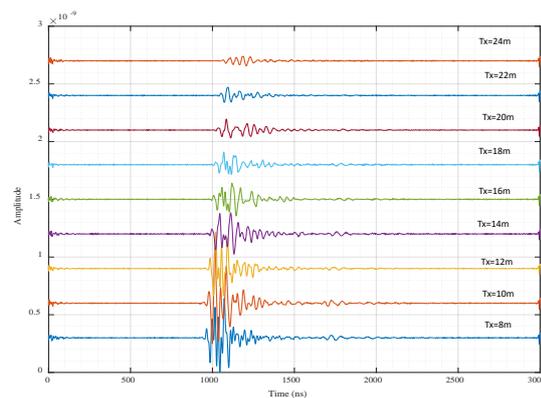
We have surveyed inside structure of the Great Pyramid in Giza, Egypt by electromagnetic methodologies. i.e., Ground Penetrating Radar (GPR). The Great Pyramid is very well known as Khufu's Pyramid, but its inside structure is not well known. A few passages and chambers are known, but some scientists think there will be more structures inside the pyramid. Scientific approaches by using GPR, micro gravity and space ray have also been carried out[1][2].

We think electromagnetic wave is a good method, but attempts using GPR has failed in 1980s. In this study, GPR operating at 80MHz have been used, but electromagnetic wave propagation even through a few meters have not been received. We think one of the reasons is the structure of pyramid. It is well known that the pyramid is made from millions of rock blocks. However, the gaps between rock blocks are 1cm-10cm, and it is quite irregular shape. WE think this gap will scatter the EM wave and the attenuation is large in higher frequencies. The inner structure of the pyramid is unknown. Some scientists think that the pyramid is not consists from rock blocks, but sand or other atrial was partially filled. It is also known that by drilling the wall of a passage inside the pyramid, they found that the inner structure was filled with sand, but not by a rock block. Basically, the pyramid is made from Lime stone brocks and Granite brocks. And by using a rock sample we determined that the relative dielectric constant is around 6.

We used frequency between 1MHz-200MHz, dominant frequency lies below 50MHz, and designed a GPR system synchronizing the transmitter and the receiver through an optical analog link. We used a compact VNA for a transmitter and receiver, and bow-tie antennas made from wire having the dipole length 4m for the transmitter and receiver antennas.



**Figure 1.** Measurement site inside the Great Pyramid



**Figure 2** Time –domain signal (Rx=21m)

Figure 2 show one example of the time-domain signals which we acquired. We found that the EM propagation though passages are strong, and EM wave propagating through rock is not easy to determine. It seems that the apparent velocity which we measure is not the same as that we determined by using a rock block. We expect that inner structure information can be extracted from the measured data.

### References

- [1] S. Yoshimura, T. Nakagawa, S. Tonouchi and K. Seki, "Non-Destructive Pyramid Investigation (2) ," Studies in Egyptian Culture, (8) 1988.
- [2] K.Morishima, et. al., "Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons," Nature, 552, pp.386–390, 2017.