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A published paper of this talk is at IEEE Xplore: https://doi.org/10.1109/IUS51837.2023.10306675)

(Details of this talk are in the paper: https://doi.org/10.36227/techrxiv.22083719)

Limited-Diffraction Beams for Secure Fast Data Communications

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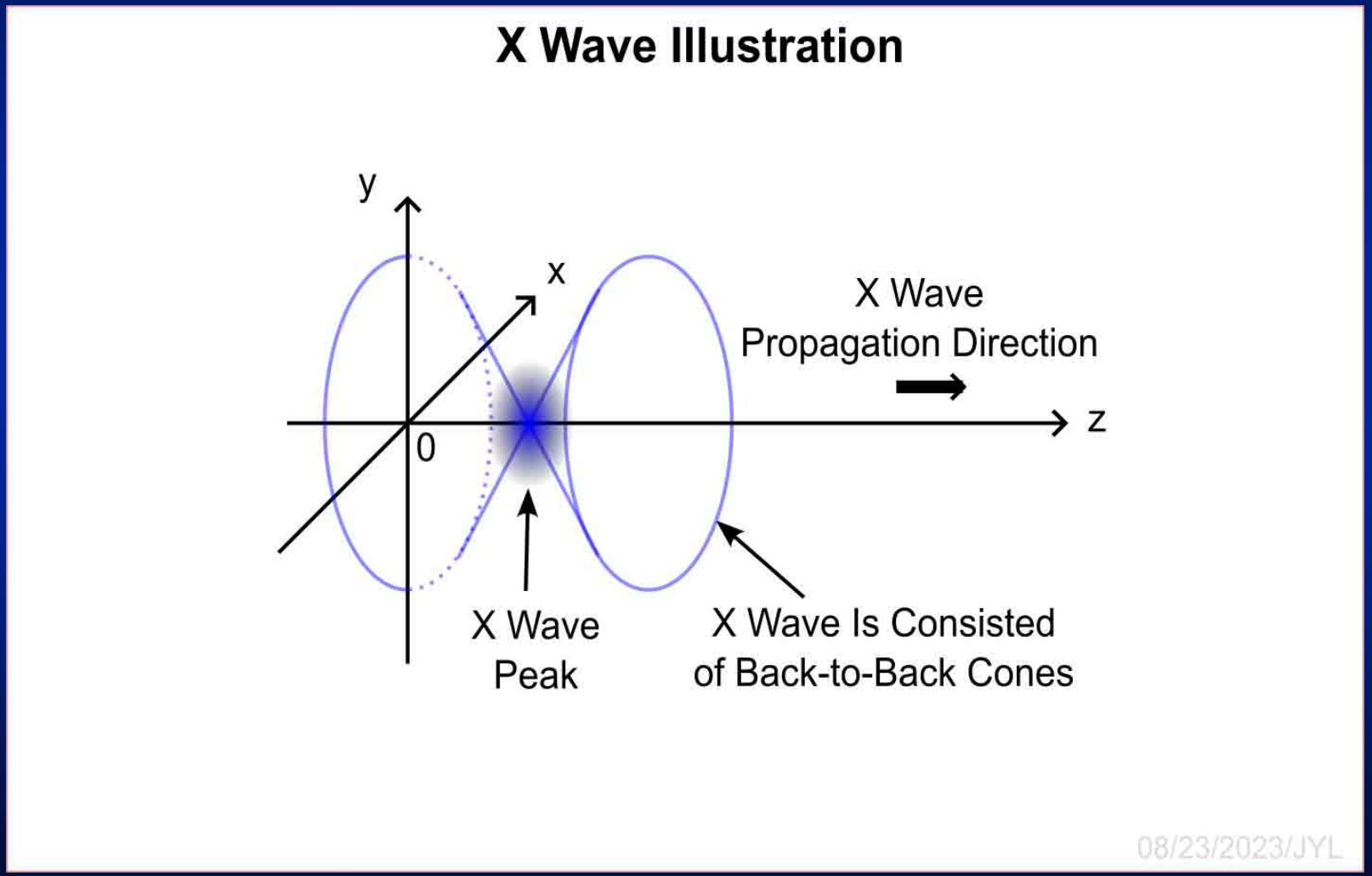
1. What Is X Wave

What Is X Wave

- **Theoretical X Wave (See the Figure in Next Slide):**
  - **(1)** It was reported first in 1991 (https://doi.org/10.1109/ULTSYM.1991.234298).
  - **(2)** It is an exact solution to the linear isotropic/homogeneous or free-space scalar wave equation.
  - **(3)** It can be highly localized of a sharp center peak in both transverse (perpendicular to the wave propagation) and axial (along the wave propagation) directions in the three-dimensional (3D) space.
  - **(4)** In theory, it can propagate to an infinite distance without changing its shape.
  - **(5)** Both the group and phase velocities of the theoretical X wave are larger than the speed of sound (supersonic) in isotropic/homogeneous media or the speed of light (superluminal) in free space or vacuum.

Figure – X Wave Illustration

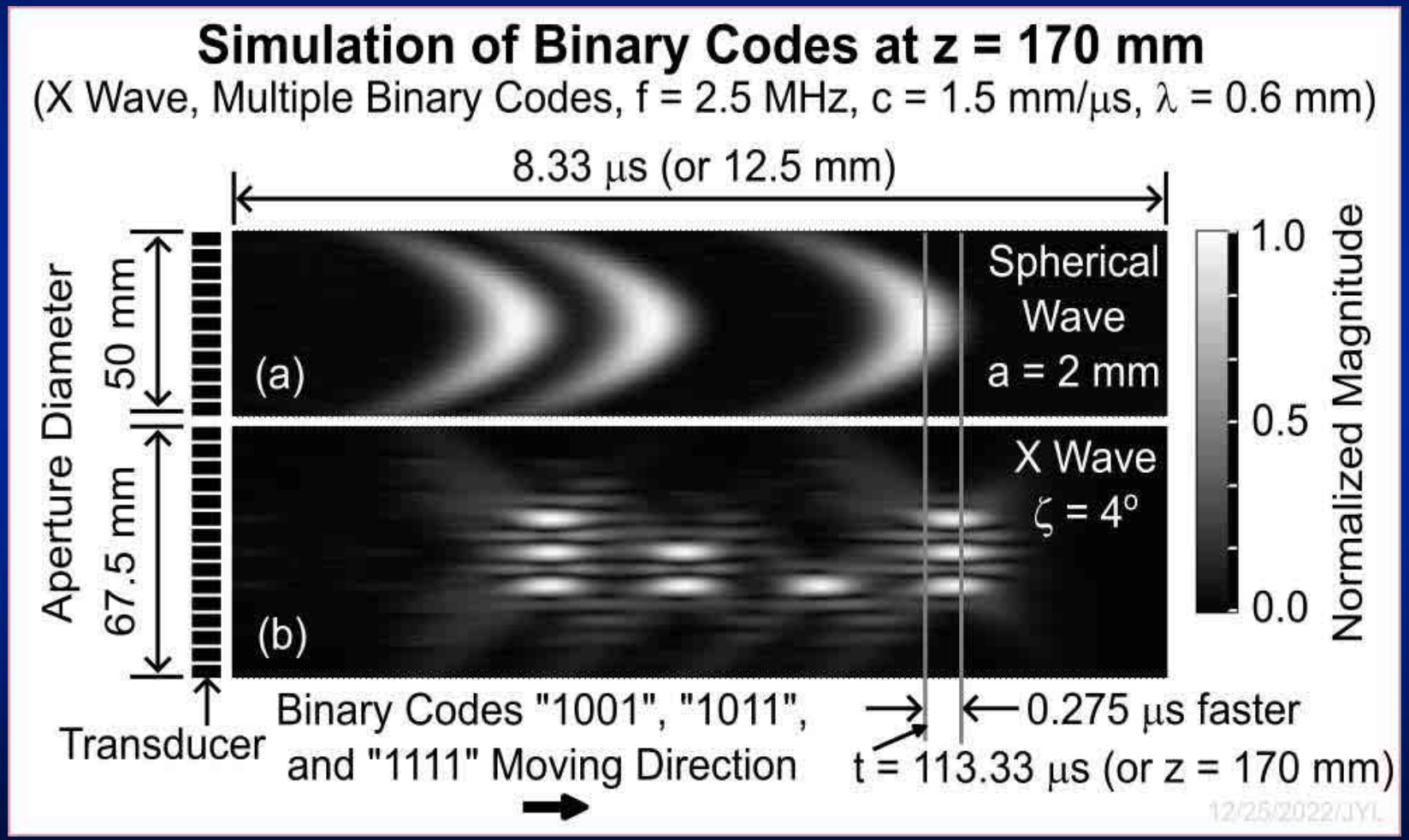


2. Applications to Multi-Channel, Secure, and High-Data-Rate Communications

Transmit Information with X Wave

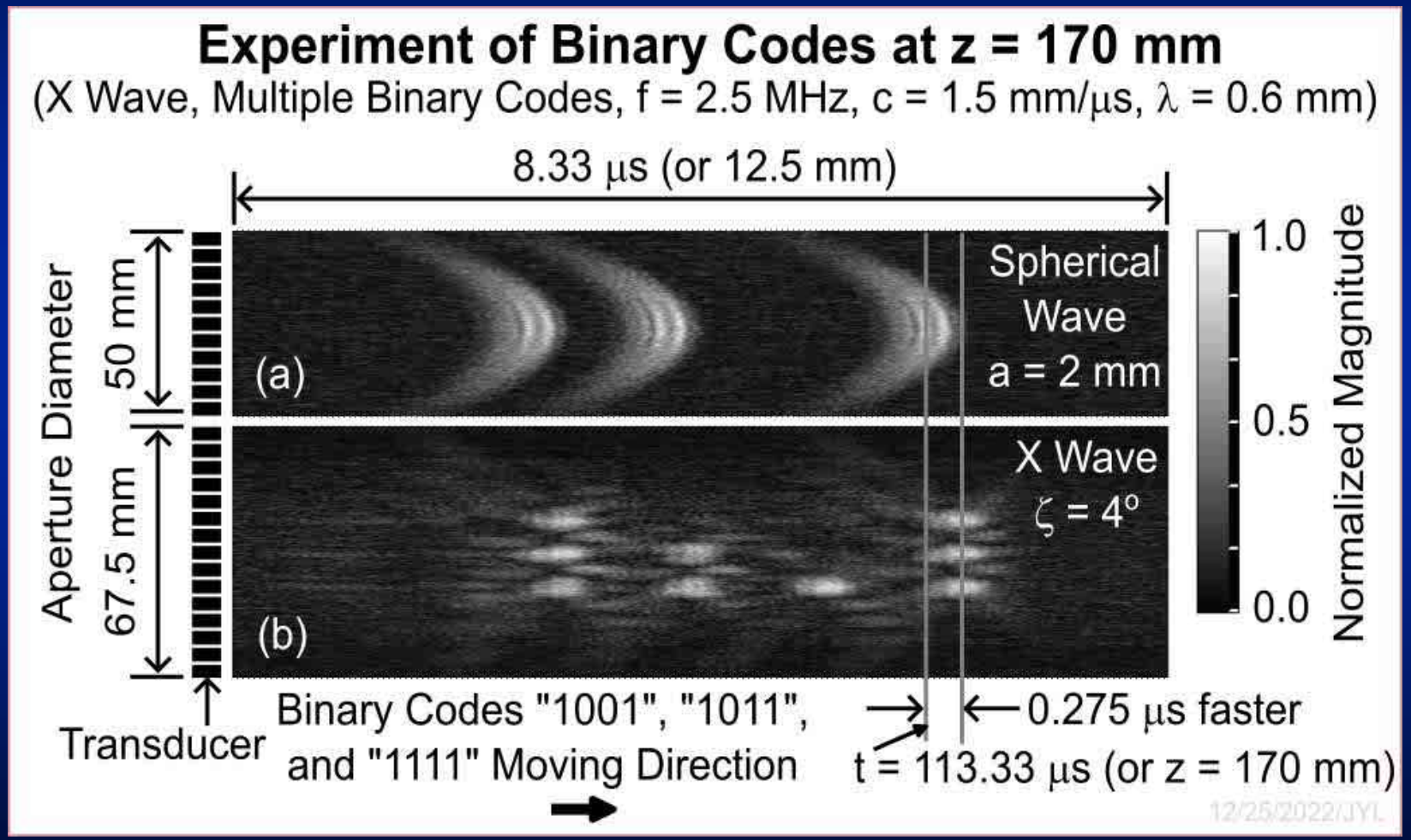
- **Transmit Information (Energy):**
  - **(1)** Because of the localization property and the supersonic group velocity, the X wave was used to transmit digital information (or energy) at a supersonic speed for secure and high-speed data communications in multiple channels.
  - **(2)** Both computer simulation and experiment were conducted using a 2.5-MHz ultrasound transducer in water.
  - **(3)** The results show that even with a finite transducer aperture, the X wave has a very large depth of field and is nondispersive (the wave speed does not change with the temporal frequency).
  - **(4)** Note: The digital information transmitted supersonically contains energy, otherwise the hydrophone used in the experiment cannot receive a signal.

Simulation – X Wave Communication



Binary codes are read from right to left, and order n = 0 for X wave

Experiment – X Wave Communication



Binary codes are read from right to left, and order n = 0 for X wave

3. Implications of Supersonic X Wave Experiment

Implications of Supersonic X Wave Experiment

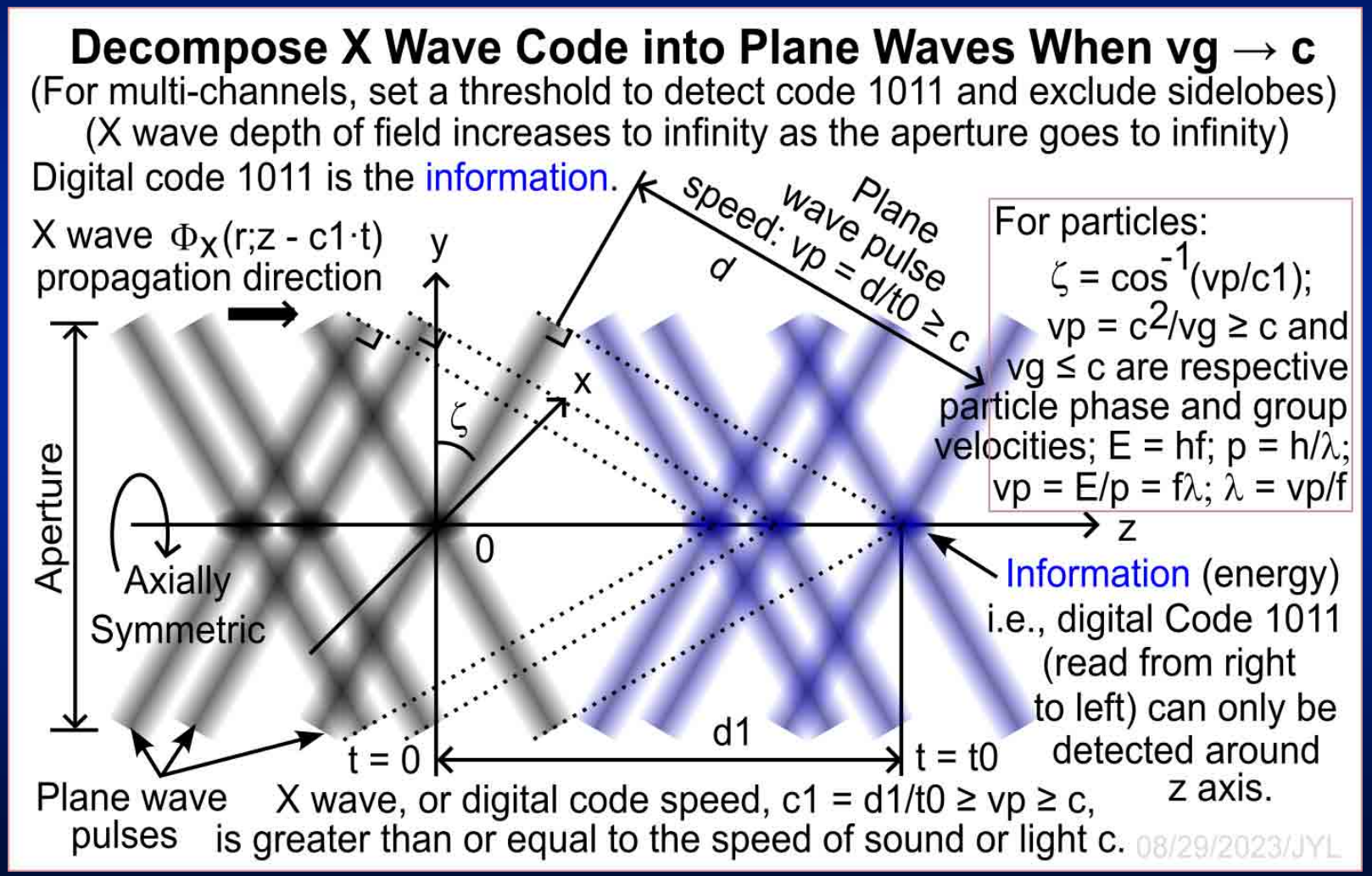
- **Implications:**
  - **(1)** Since the ultrasound experiment shows that the X wave can transmit digital information at a supersonic speed and the ultrasound X wave shares the same wave equation as the light or electromagnetic waves, X wave also can transmit information (energy) at a speed that is greater than the speed of light in free-space or vacuum.
  - **(2)** In 2023, the author has developed X wave solutions to the free-particle Dirac, Klein-Gordon, and Weyl equations in quantum mechanics (see DOI: https://doi.org/10.36227/techrxiv.22083719 for details). Given the superluminal group velocity of these X waves, it is possible that both the massive and massless particles can be used to transmit information (energy) at a speed that is larger than the speed of light in free space or vacuum.
  - **(3)** Note: The reason why the X wave is superluminal can be explained by the Heisenberg's uncertainty principle.

4. Conclusion

Conclusion

- **Conclusion:**
  - **(1)** X wave is highly localized in the 3D space and can be used to transmit digital information (energy) faster than the speed of sound in water (supersonic), as is shown in both the computer simulation and experiment.
  - **(2)** Thus, the X wave can be tightly packed in space to form multiple channels for secure and high-data-rate communications.
  - **(3)** Since the electromagnetic, optical, and particle X waves share the same or similar scalar wave equations as the ultrasound X wave, they can be used to transmit digital information (energy) faster than the speed of light in free space or in vacuum.

Figure – X Wave Decomposition (aperture →∞, truncated X wave → theoretical X wave)



Key Questions of the Study

- **Key Questions:**
  - **(1)** Is the digital code such as “1011” information? [Answer: Yes.]
  - **(2)** Does the digital code “1011” contains energy? [Answer: Yes.]
  - **(3)** Can the digital code “1011” travel faster than the speed of sound or light? [Answer: Yes.] ($\zeta \rightarrow 0$, X wave $\rightarrow$ plane wave, speed $\rightarrow$ $vp \geq c$.)
  - Since the answers to the questions above are “Yes”, it should not matter how the digital code is produced or how the phenomenon (faster than the speed of sound or light) is interpreted, such as “light shadow”, “scissors”, and so on, as long as such digital code, say, “1011” can be produced, has practical applications such as multi-channel secure and high-data-rate communications, and the correspondence principle is not violated.
  - **Note:** Correspondence principle requires that any new theories should “explain all the phenomena for which a preceding theory was valid.”

Thank You !

Questions ?

Discovery / Invention