Title: Tomography without trusted apparatus

Date: Aug 29, 2008 02:00 PM

URL: http://pirsa.org/08080046

Abstract: I will talk about \'self-testing\' quantum apparatus.

Tomography with untrusted apparatus?

Michele Mosca

Based on self-testing work with F. Magniez, D. Mayers, M. McKague, H. Ollivier

29 August 2008

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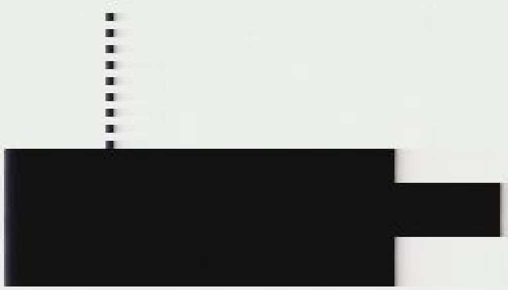

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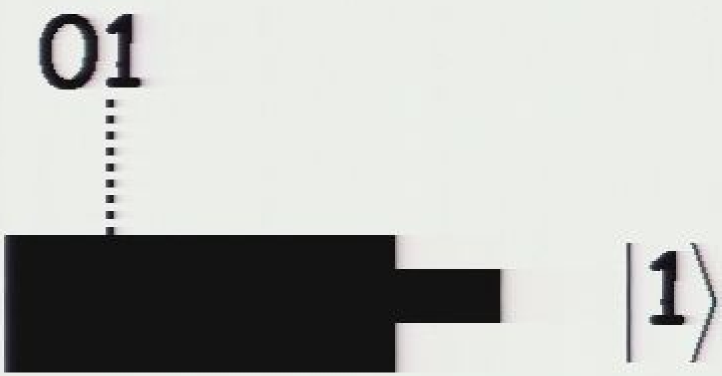

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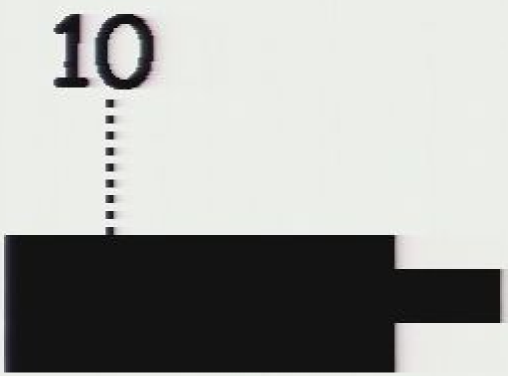

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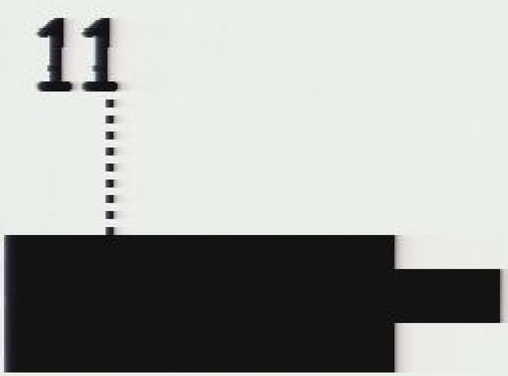

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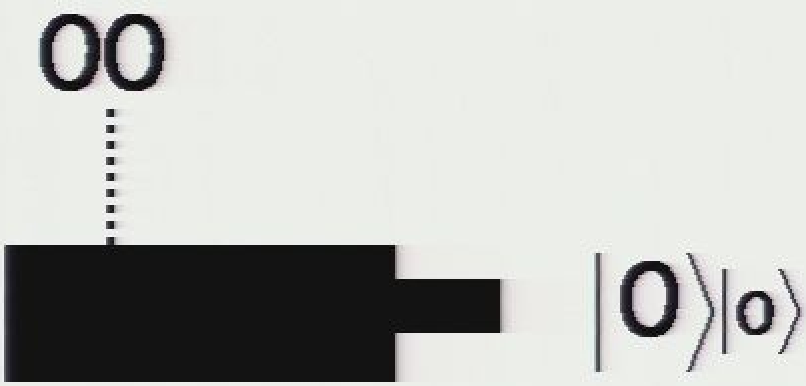

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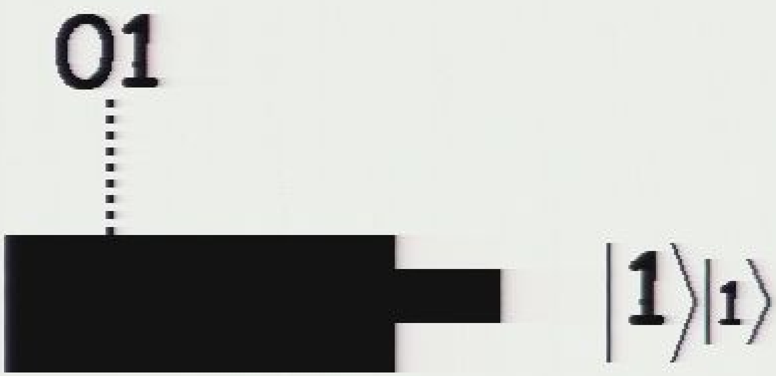

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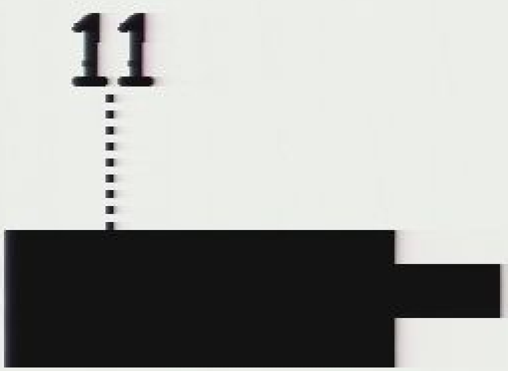

$$\frac{|0\rangle - |1\rangle}{\sqrt{2}}|3\rangle$$

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"side-channels"

http://www.research.ibm.com/journal/rd/481/smolin.html

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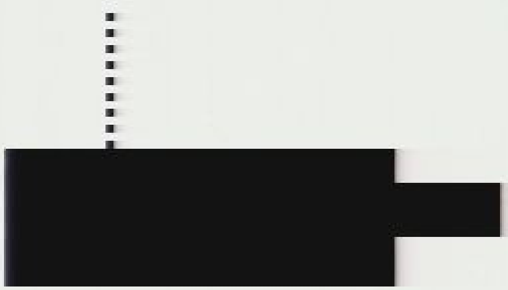

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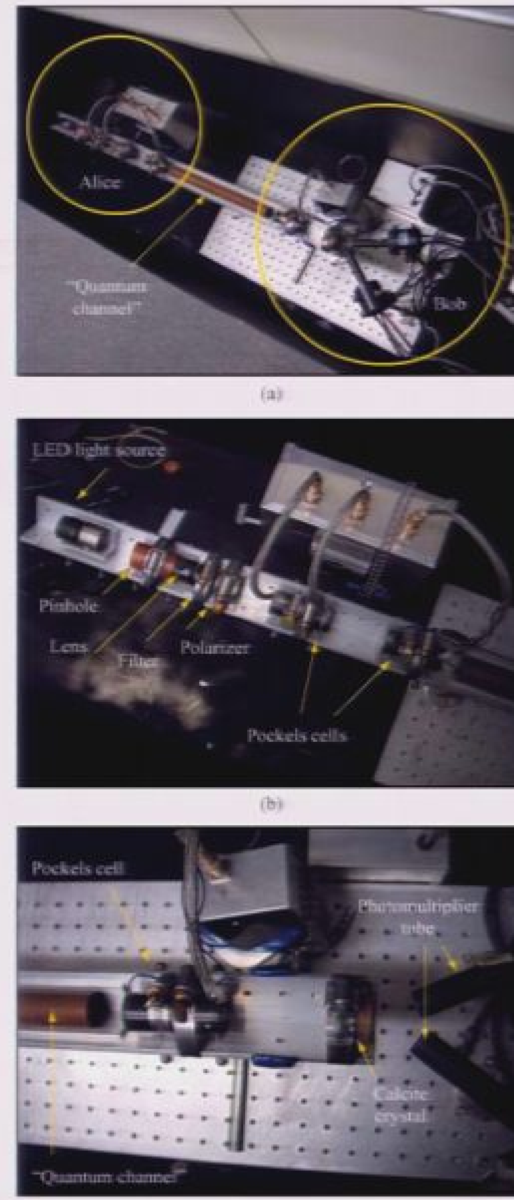

(c)

Figure 1

The apparatus used to perform the fi[illegible] cryptography experiment: (a) The entire apparatus; (b) detailed view of Alice; (c) detailed view of Bob.

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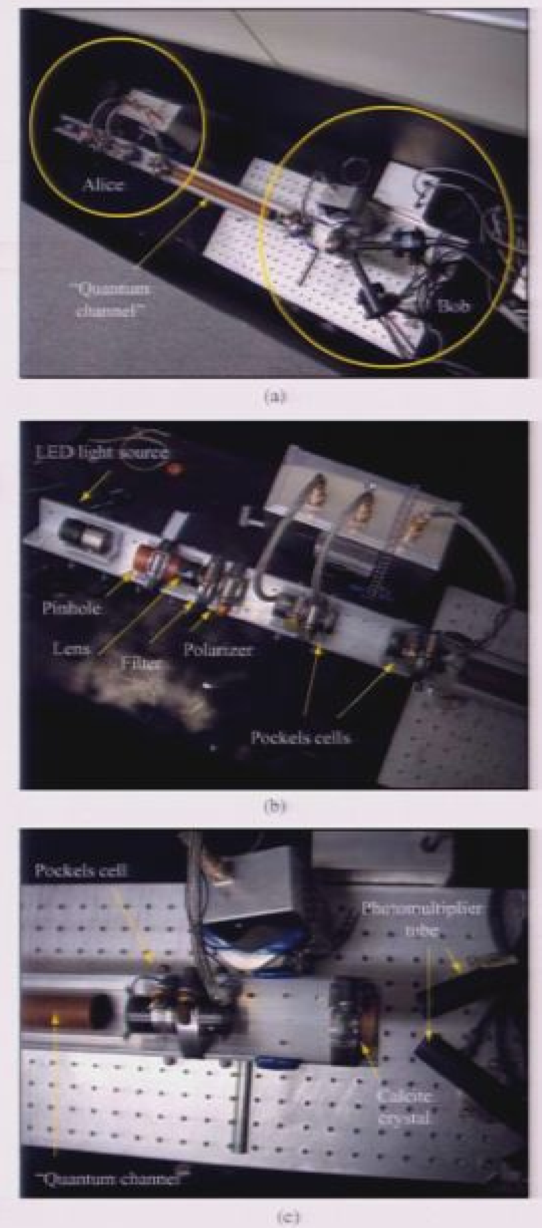

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(see Zhao et al. arXiv:0704.3253)

We need to make our assumptions and testing procedures explicit.

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We also don't want to rely on some other untrusted apparatus (e.g. in order to "just" do tomography).

SIAM J. COMPUT.
Vol. 26, No. 5, pp. 1524–1540, October 1997

QUANTUM COMPUTABILITY*

LEONARD M. ADLEMAN[†], JONATHAN DEMARRAIS[†], AND MING-DEH A. HUANG[†]

Abstract. In this paper some theoretical and (potentially) practical aspects of quantum computing are considered. Using the tools of transcendental number theory it is demonstrated that quantum Turing machines (QTM) with rational amplitudes are sufficient to define the class of bounded error quantum polynomial time (BQP) introduced by Bernstein and Vazirani [*Proc. 25th ACM Symposium on Theory of Computation*, 1993, pp. 11–20, *SIAM J. Comput.*, 26 (1997), pp. 1411–1473]. On the other hand, if quantum Turing machines are allowed unrestricted amplitudes (i.e., arbitrary complex amplitudes), then the corresponding BQP class has uncountable cardinality and contains sets of all Turing degrees. In contrast, allowing unrestricted amplitudes does not increase the power of computation for error-free quantum polynomial time (EQP). Moreover, with unrestricted amplitudes, BQP is not equal to EQP. The relationship between quantum complexity classes and classical complexity classes is also investigated. It is shown that when quantum Turing machines are restricted to have transition amplitudes which are algebraic numbers, BQP, EQP, and nondeterministic quantum polynomial time (NQP) are all contained in PP, hence in $P^{\#P}$ and PSPACE. A potentially practical issue of designing "machine independent" quantum programs is also addressed. A single ("almost universal") quantum algorithm based on Shor's method for factoring integers is developed which would run correctly on almost all quantum computers, even if the underlying unitary transformations are unknown to the programmer and the device builder.

Key words. quantum Turing machines, quantum complexity classes

AMS subject classifications. 68Q05, 68Q10, 68Q15

PII. S0097539795293639

A model of quantum computation where the computer does a tomography of some of its components

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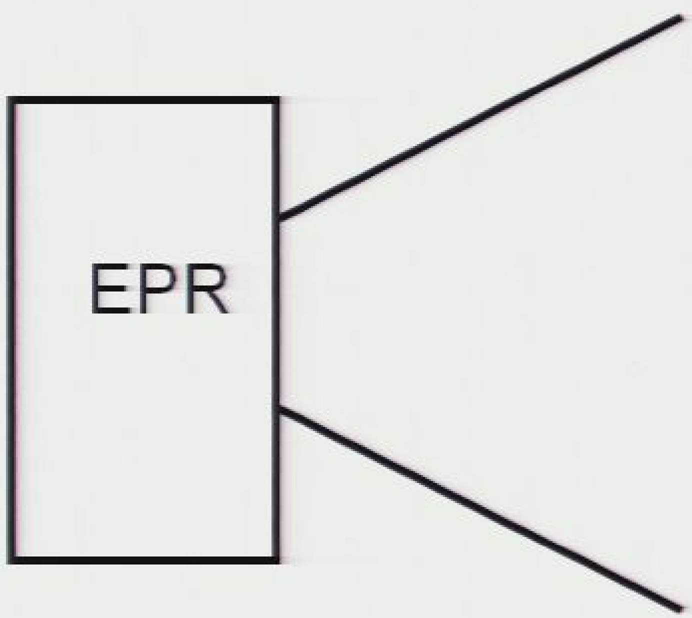

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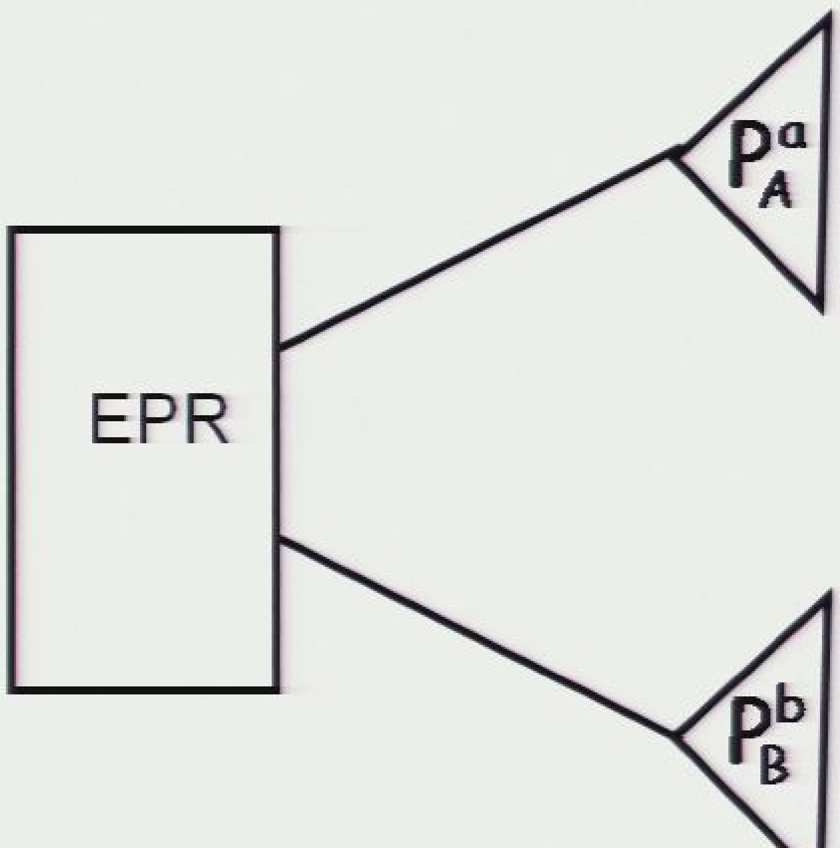

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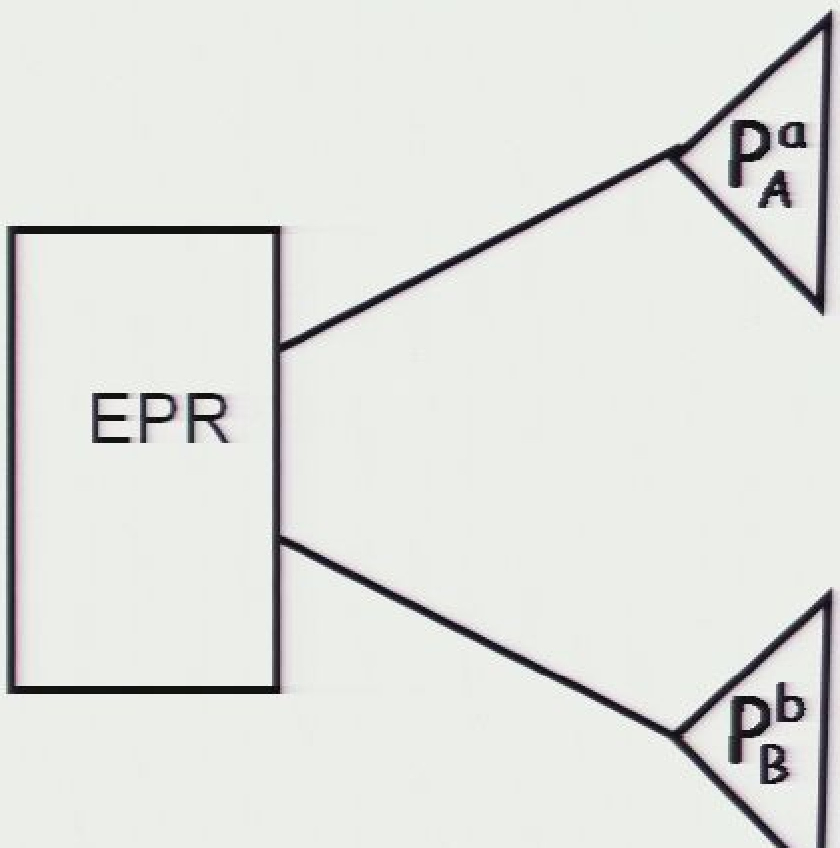

$$P^0 + P^{\pi/2} = I$$

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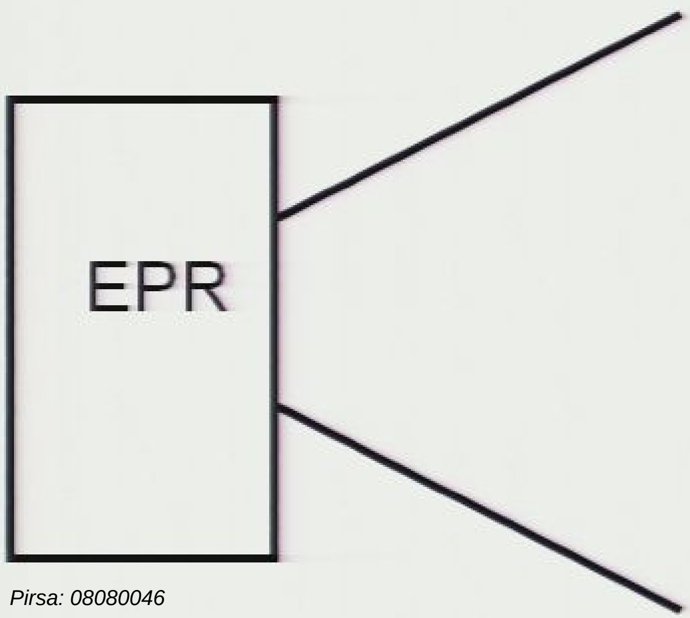

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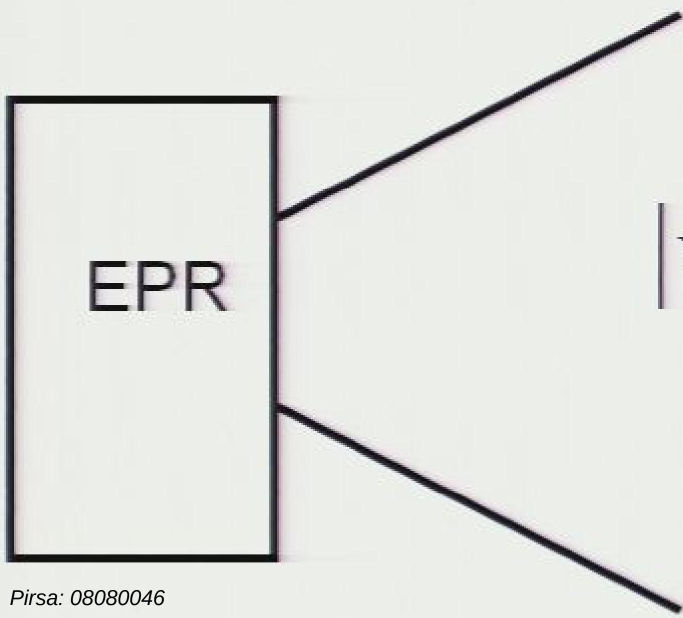

$$|\psi\rangle_{AB}$$

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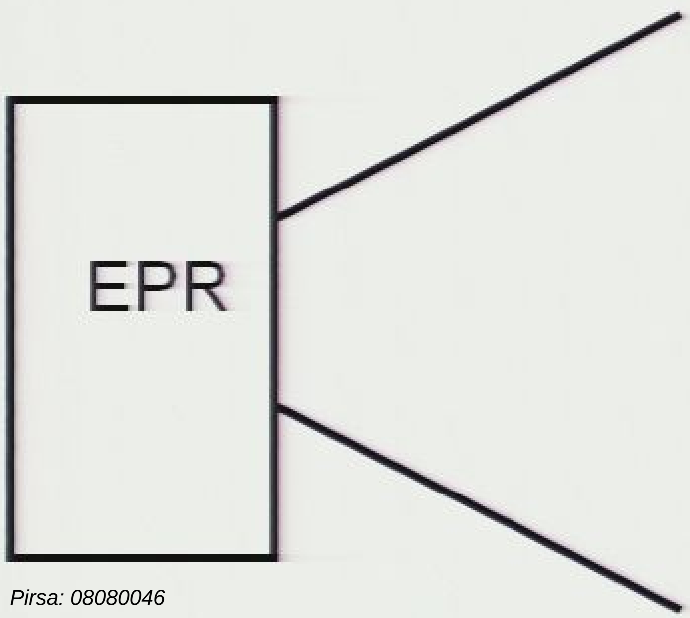
Application of this result



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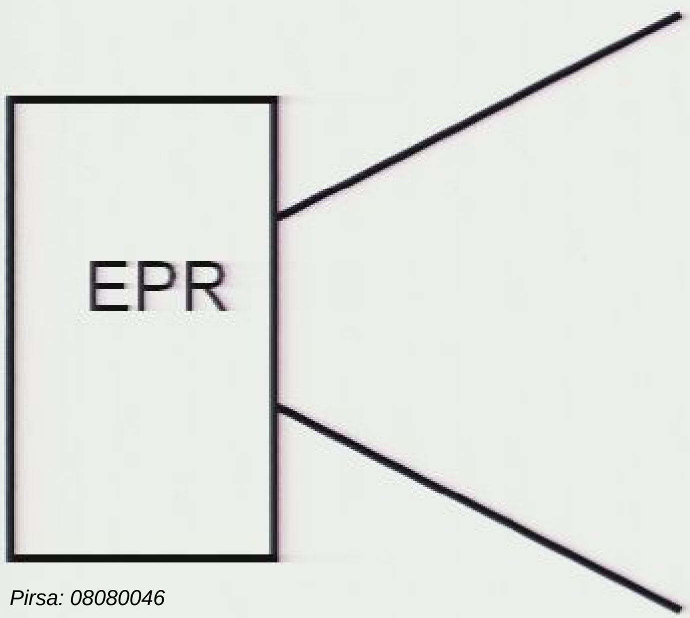

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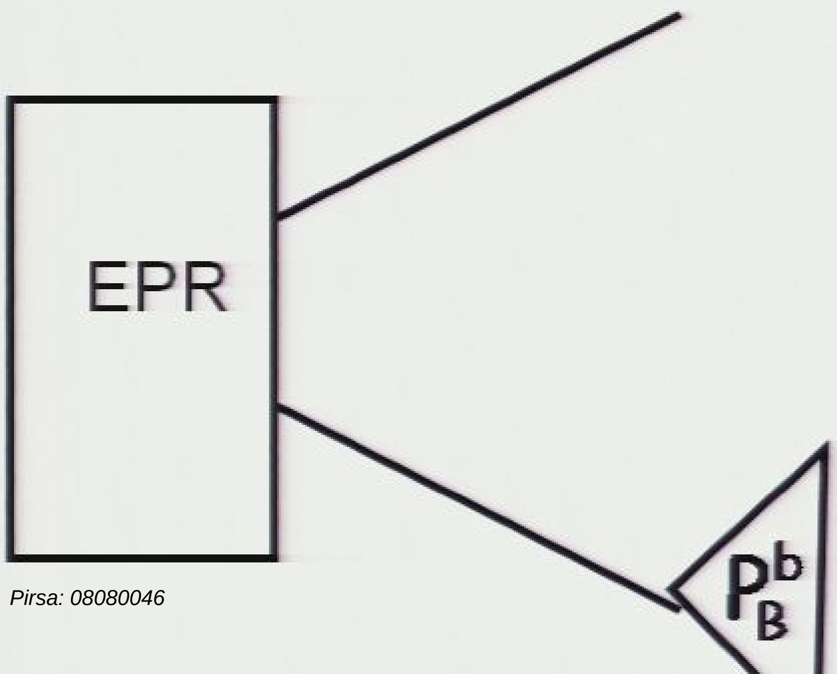

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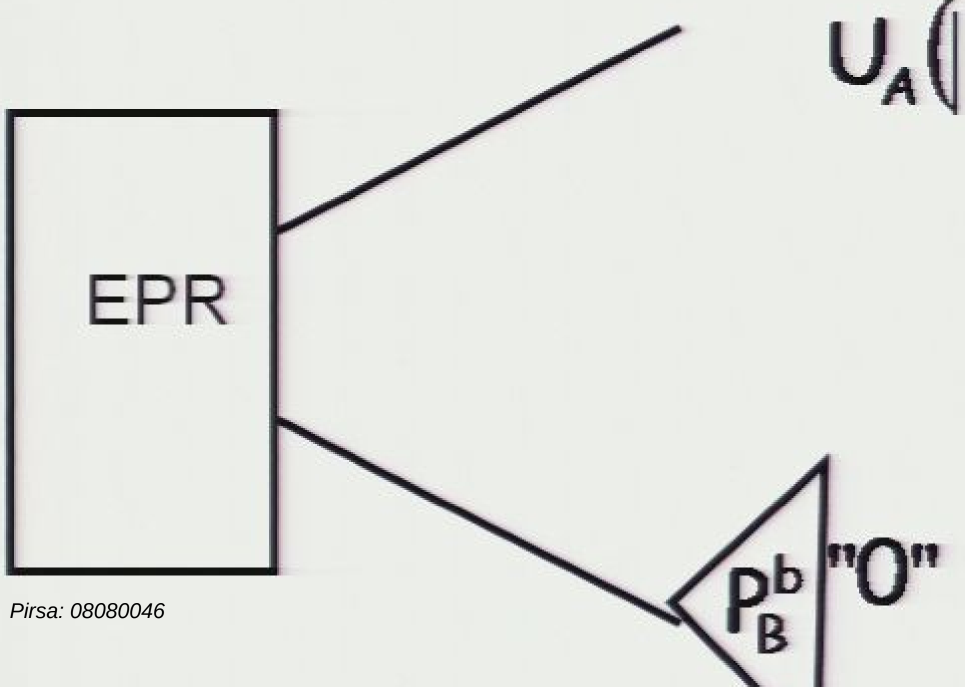

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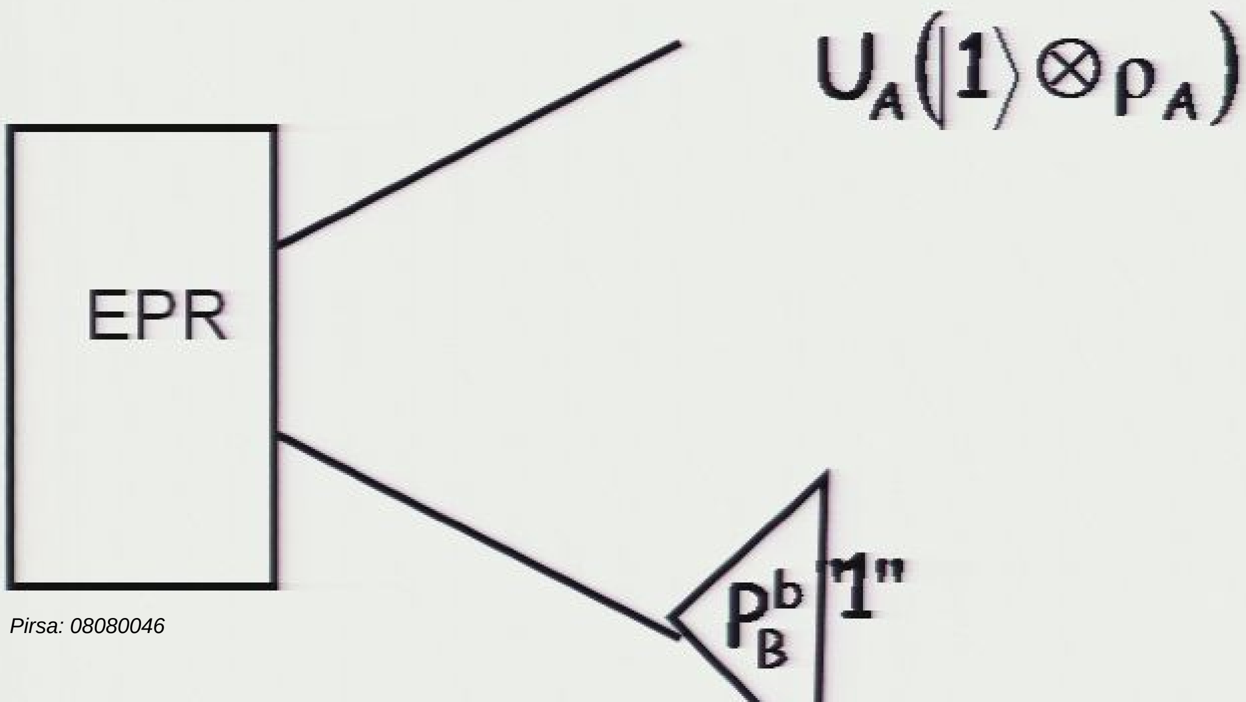

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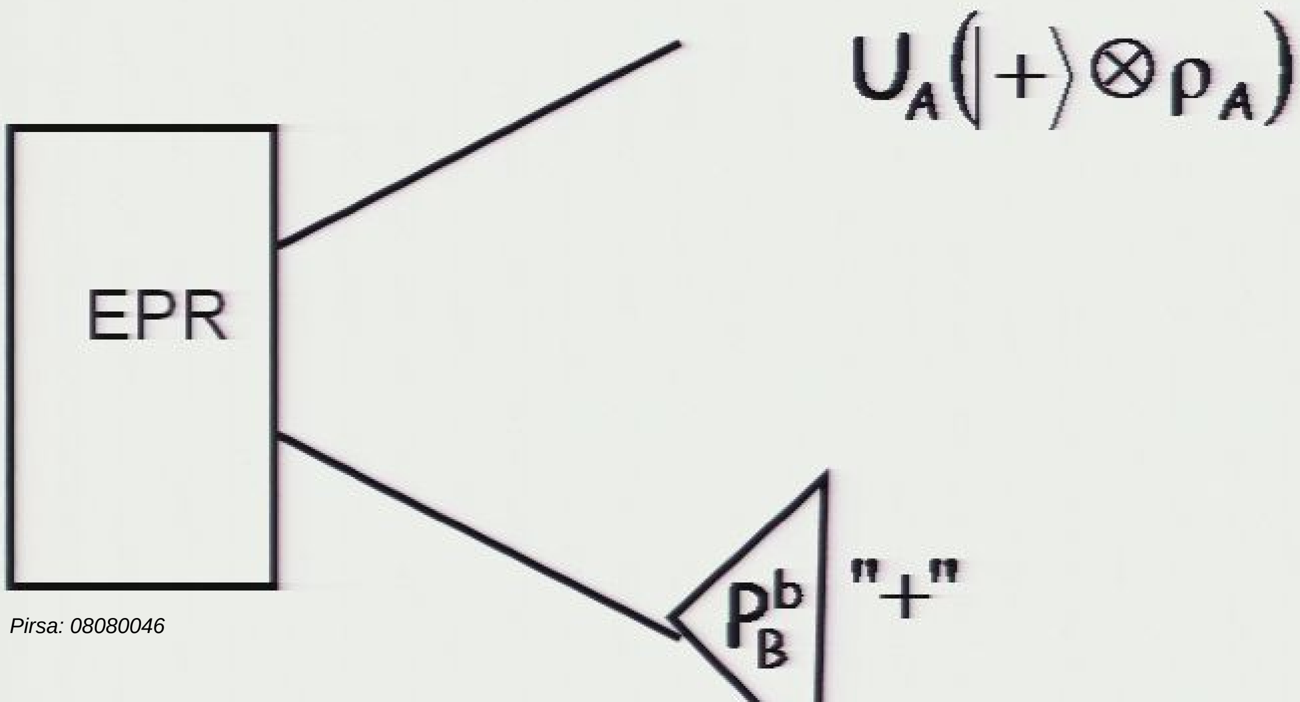

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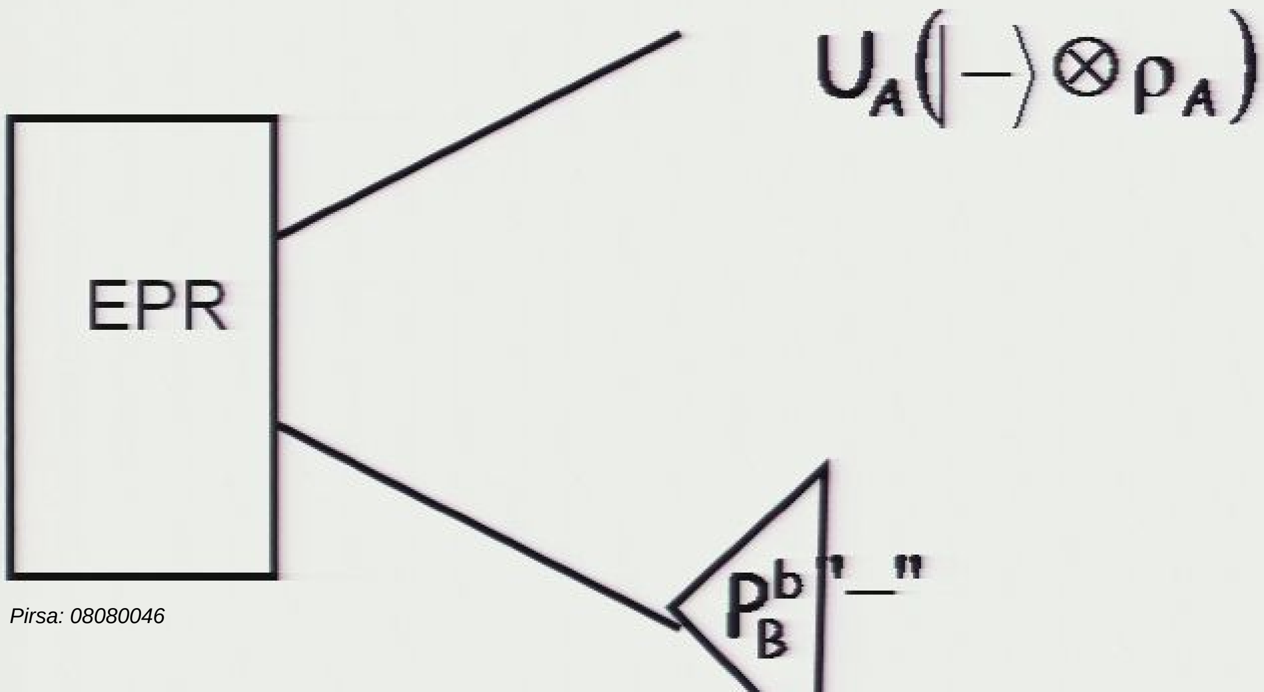

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7) The dimension of the physical systems storing the qubits was known (i.e. 2-level systems)

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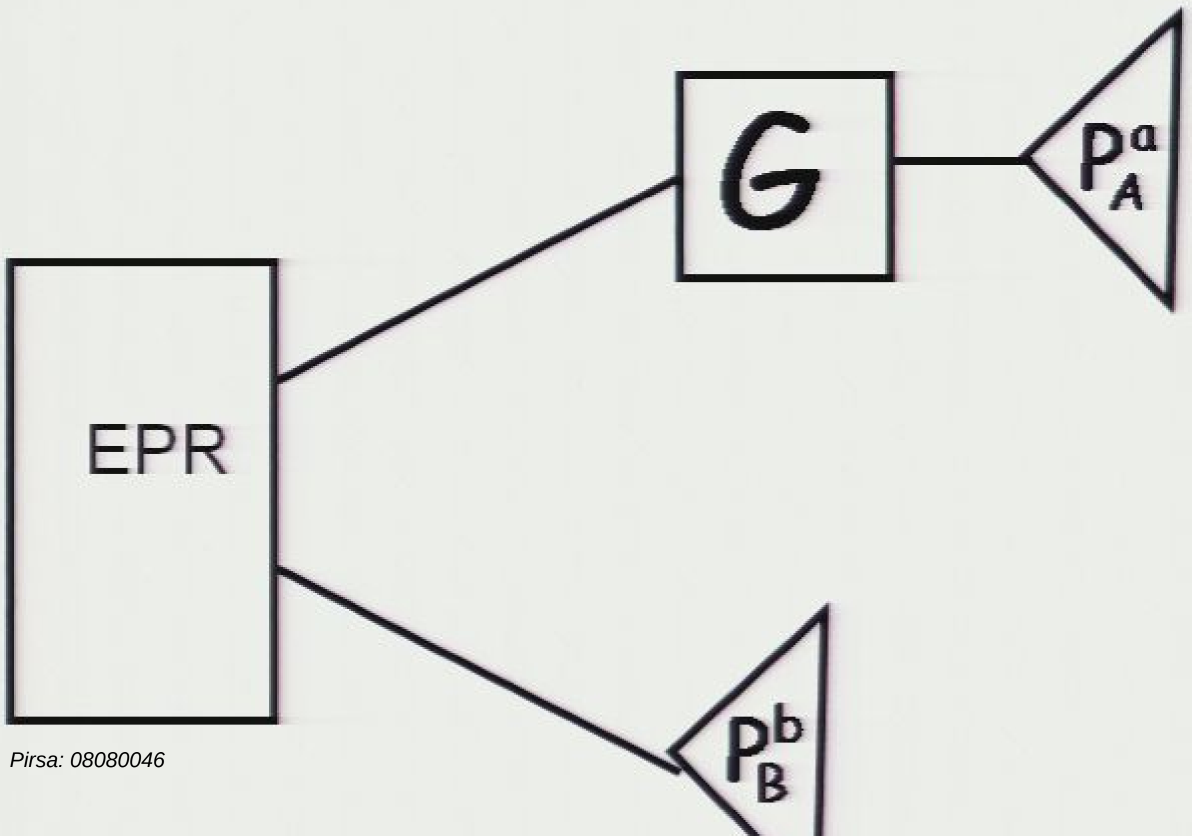

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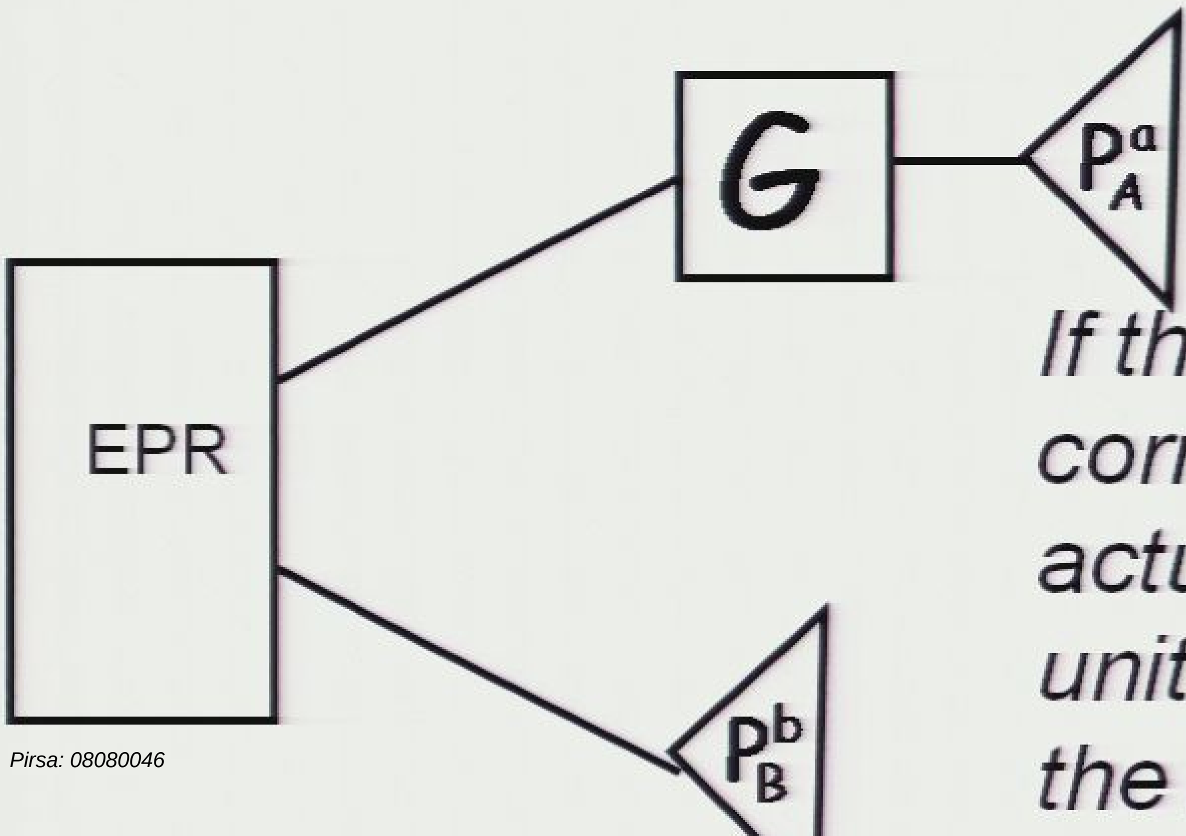

If the statistics are correct, then the actual gate G is locally unitarily equivalent to the ideal gate, T.

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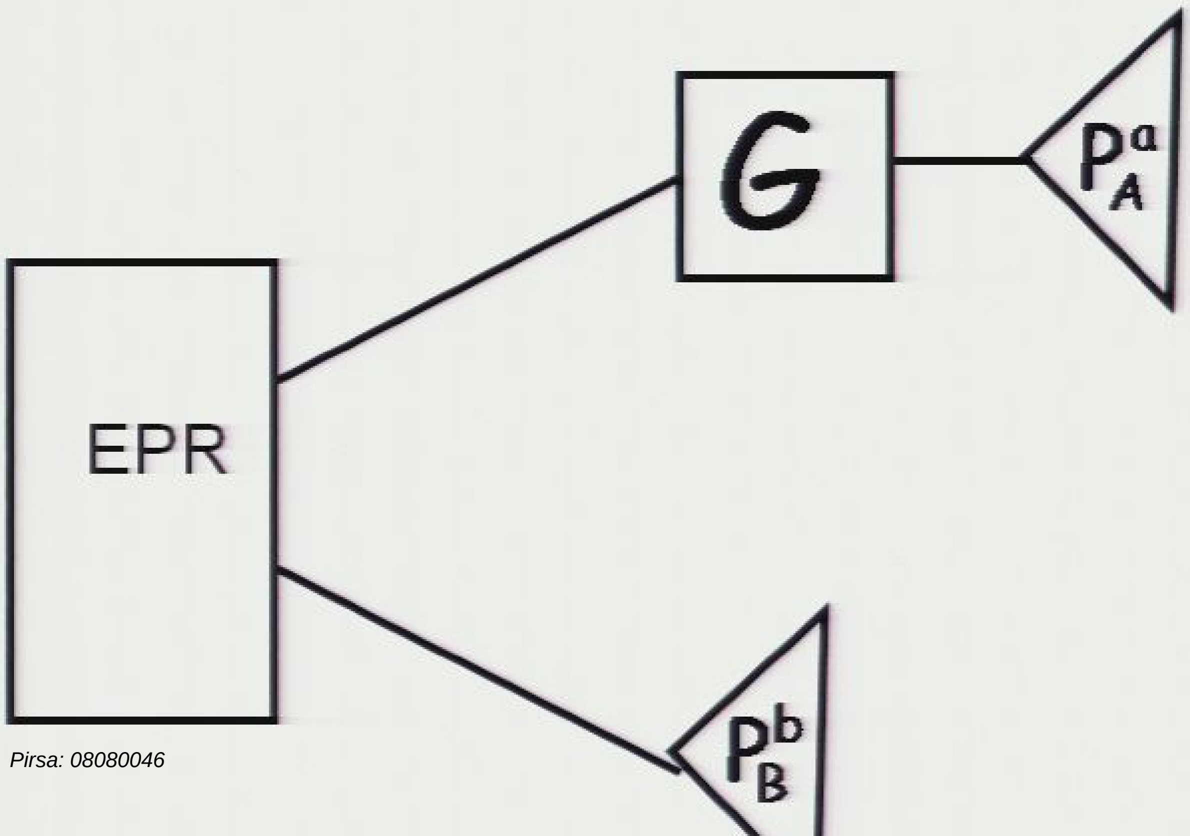

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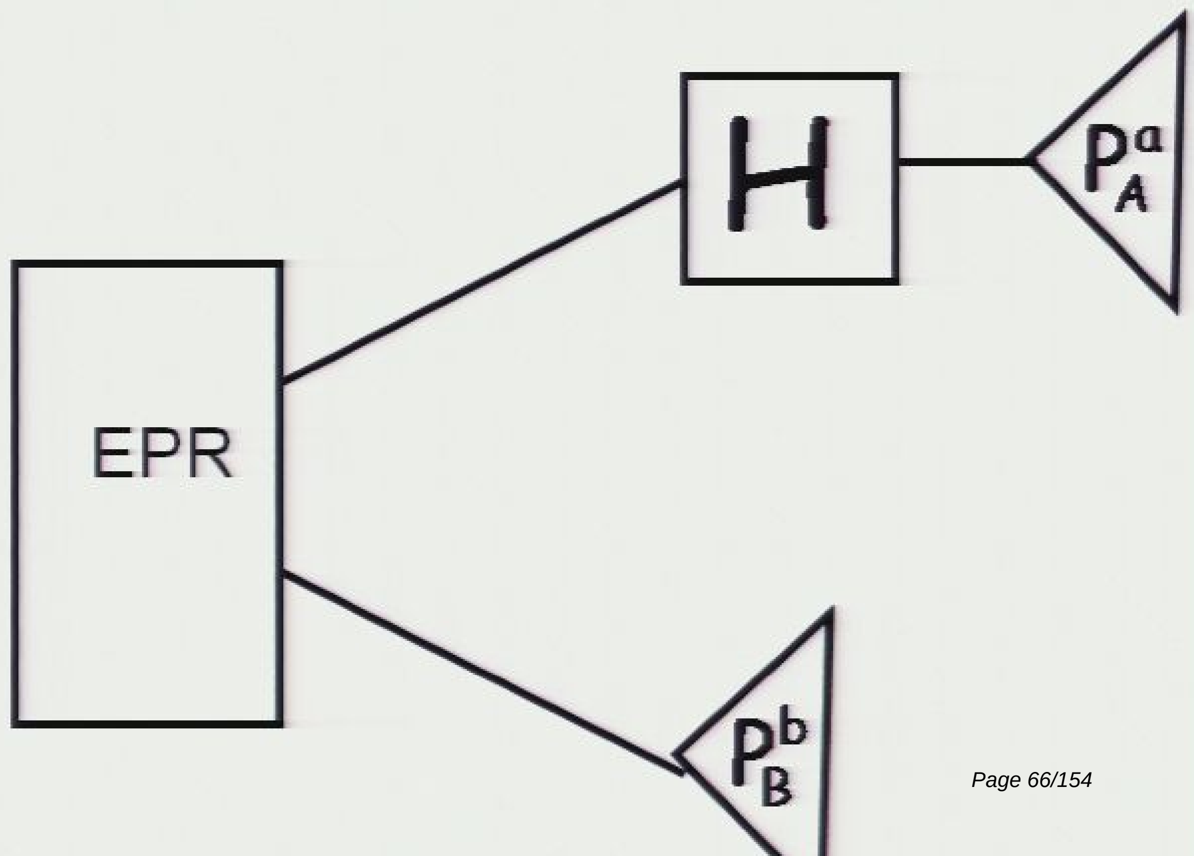

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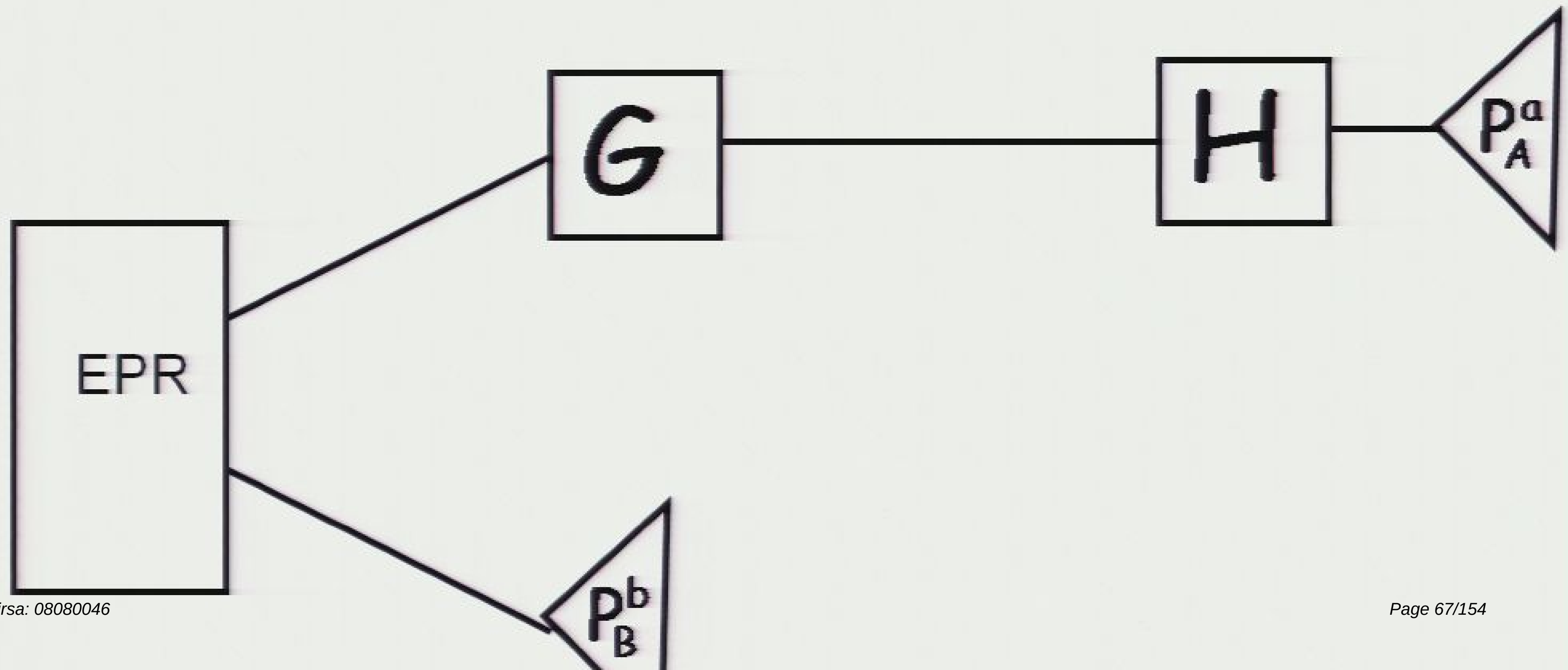

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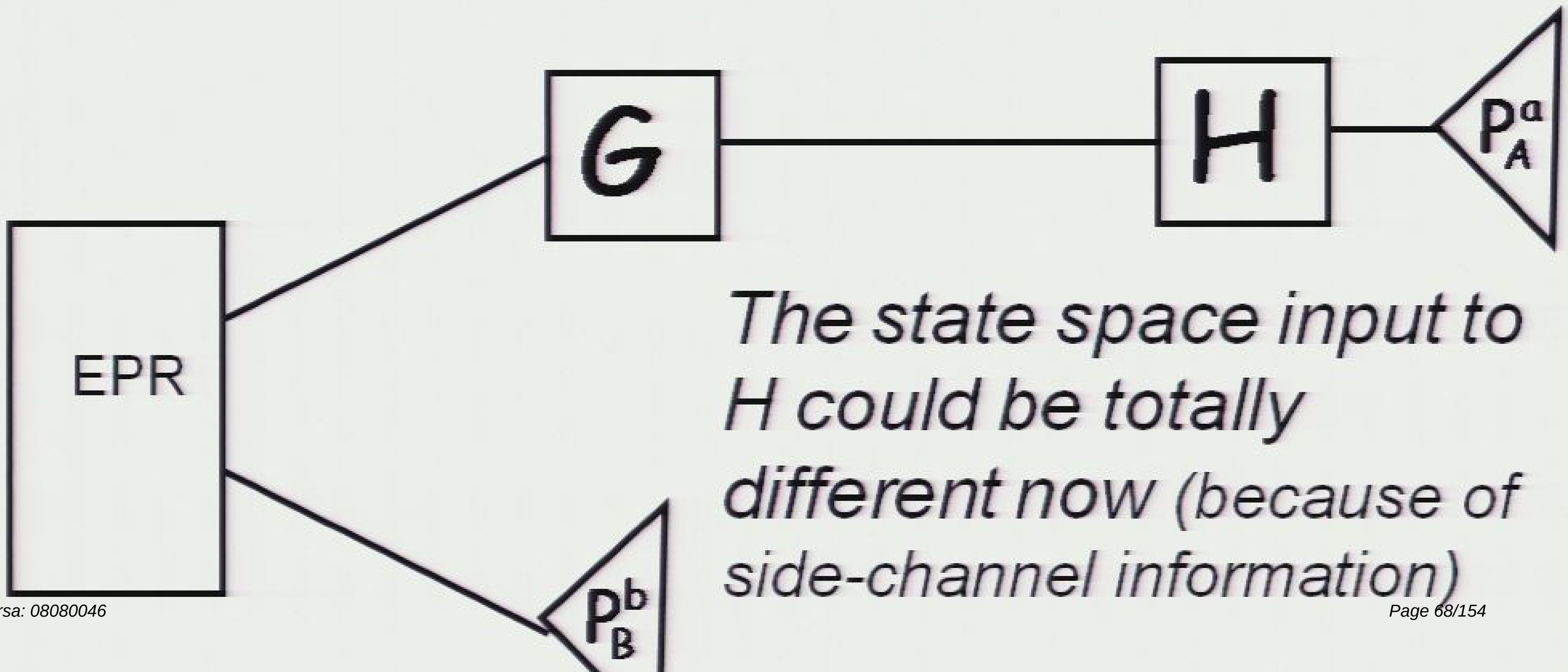

The state space input to H could be totally different now (because of side-channel information)

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We ultimately wish to test the performance of an entire circuit (note that the circuits now flow up)

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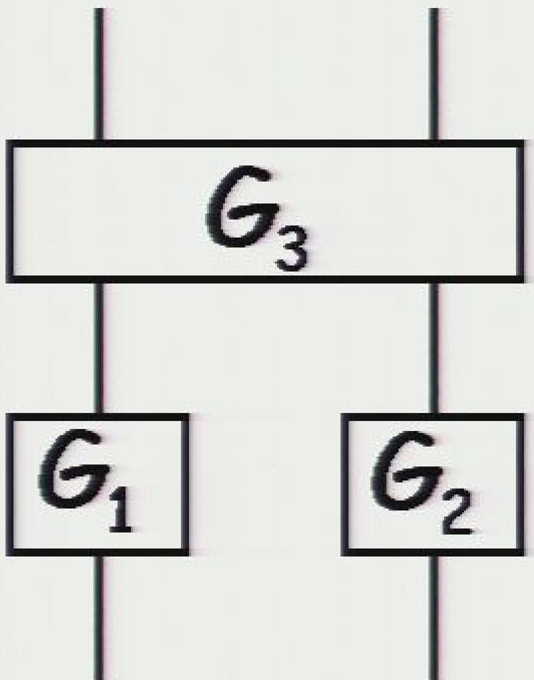

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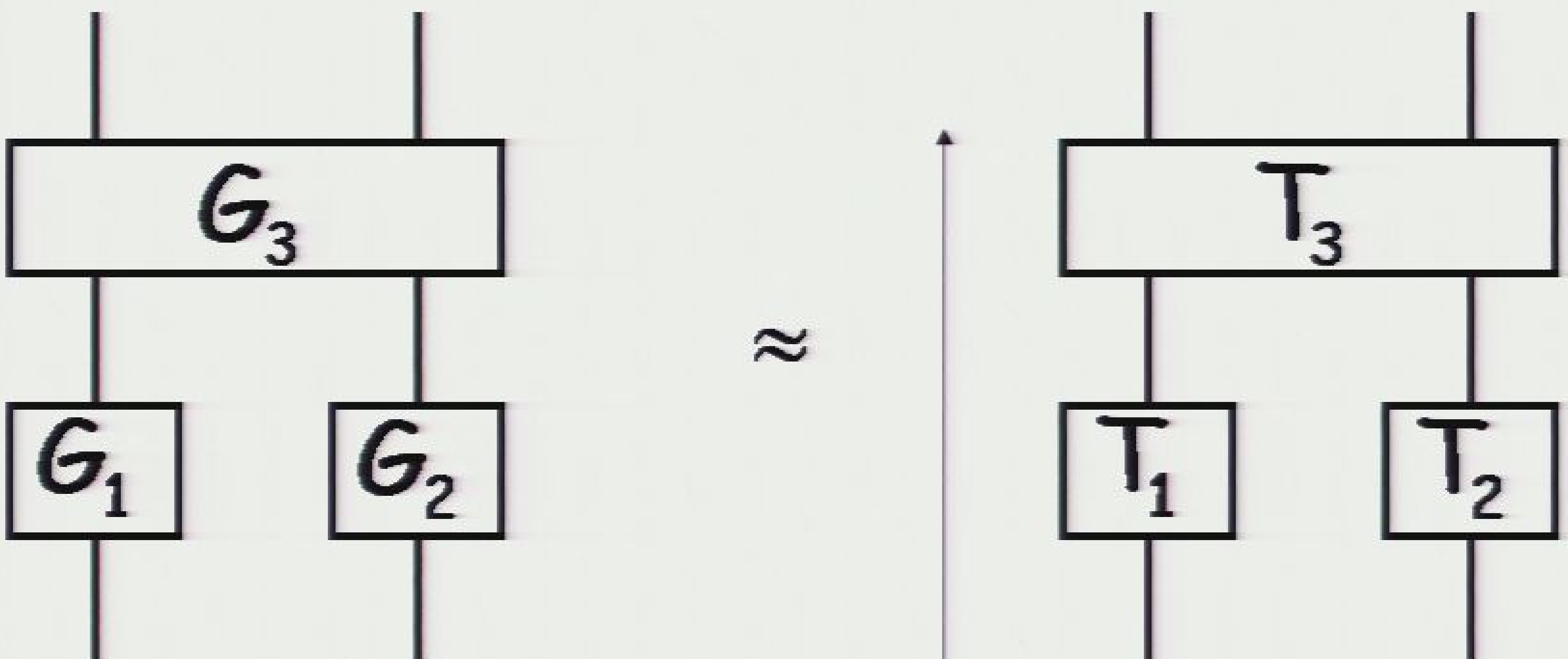

"actual physical gates" *"ideal gates"*

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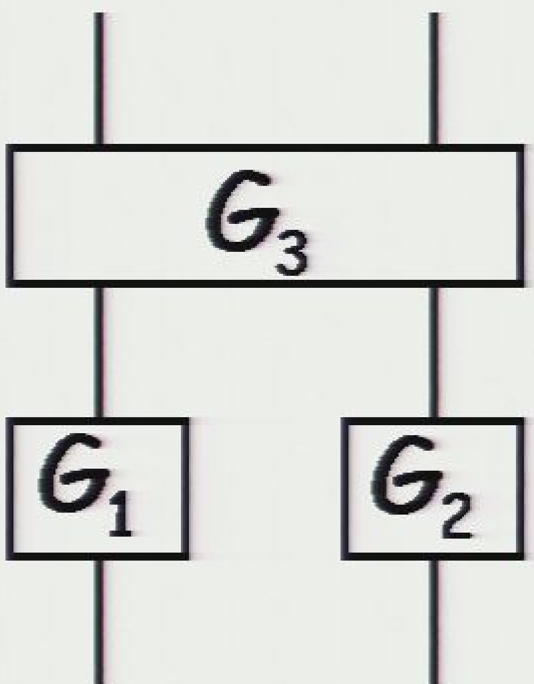

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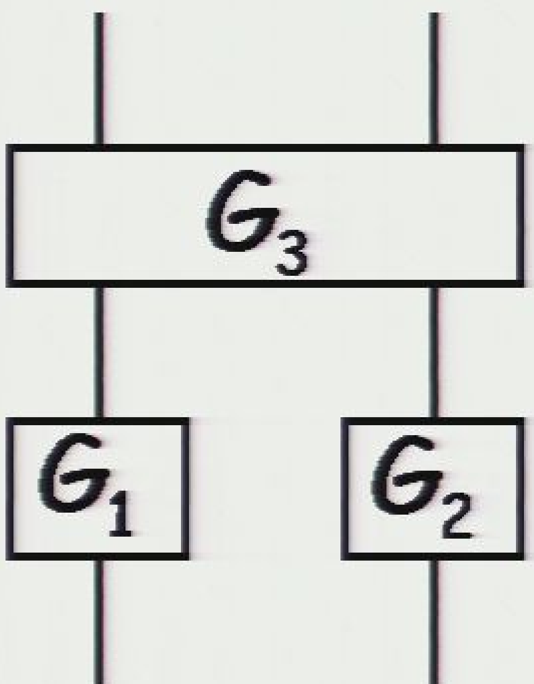

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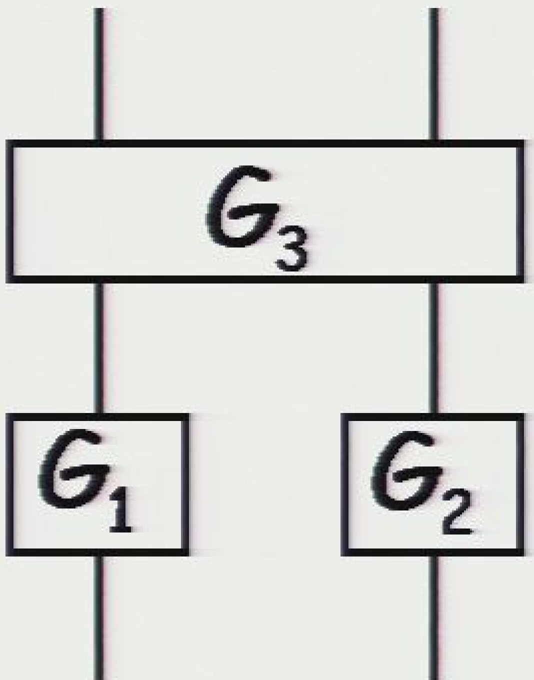

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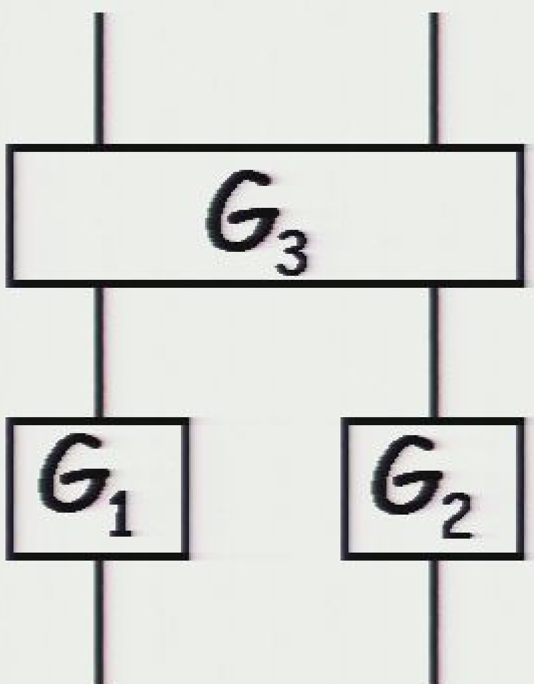

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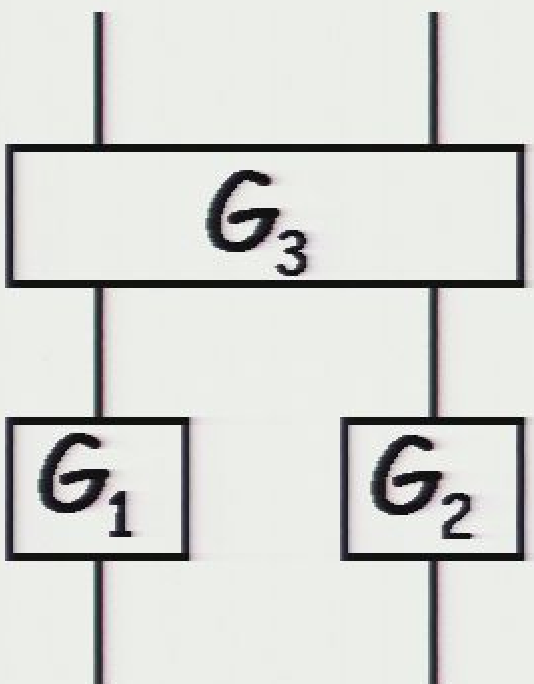

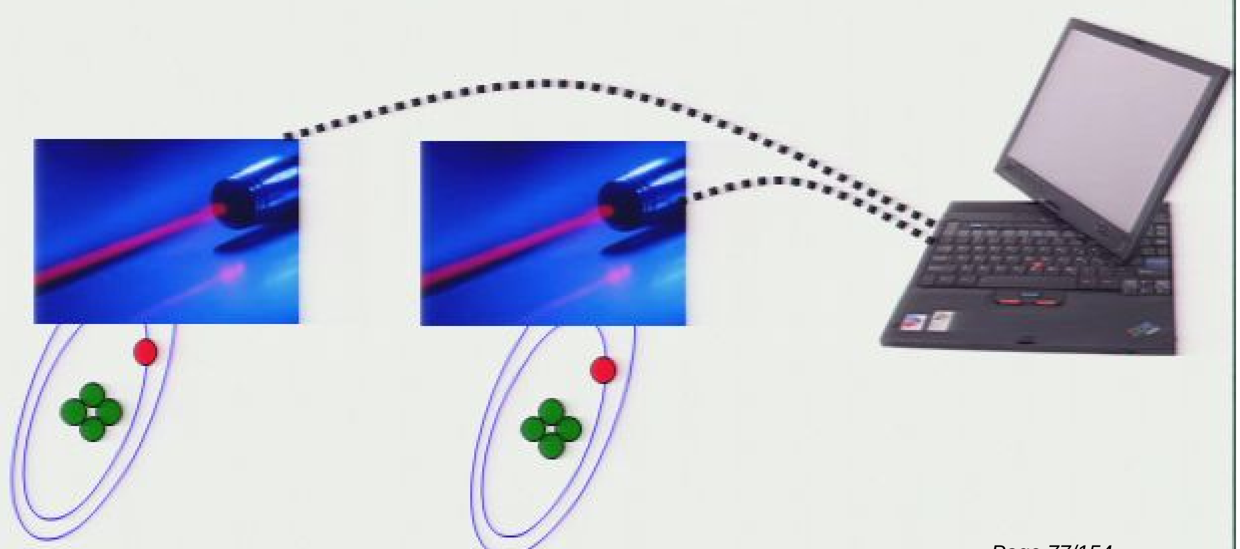

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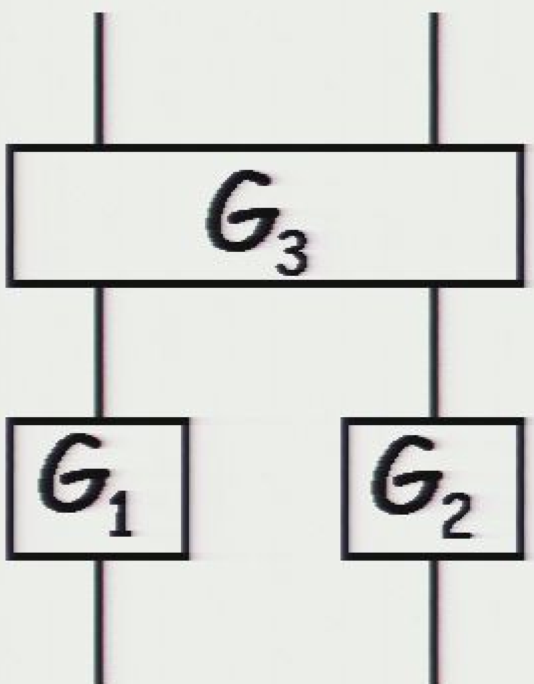

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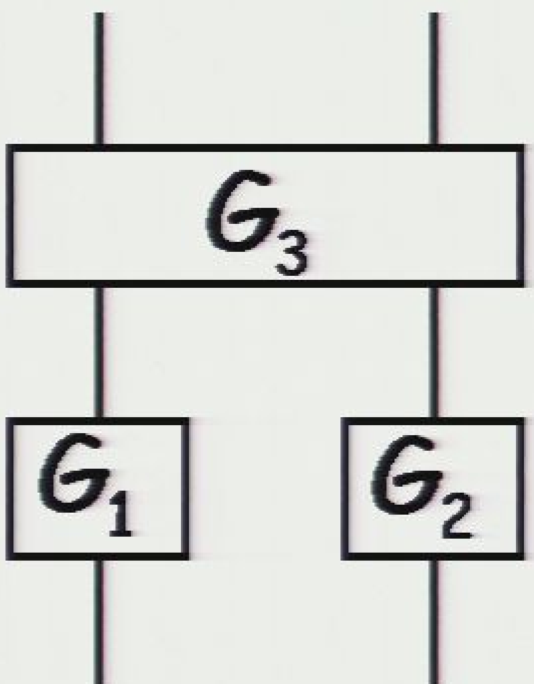

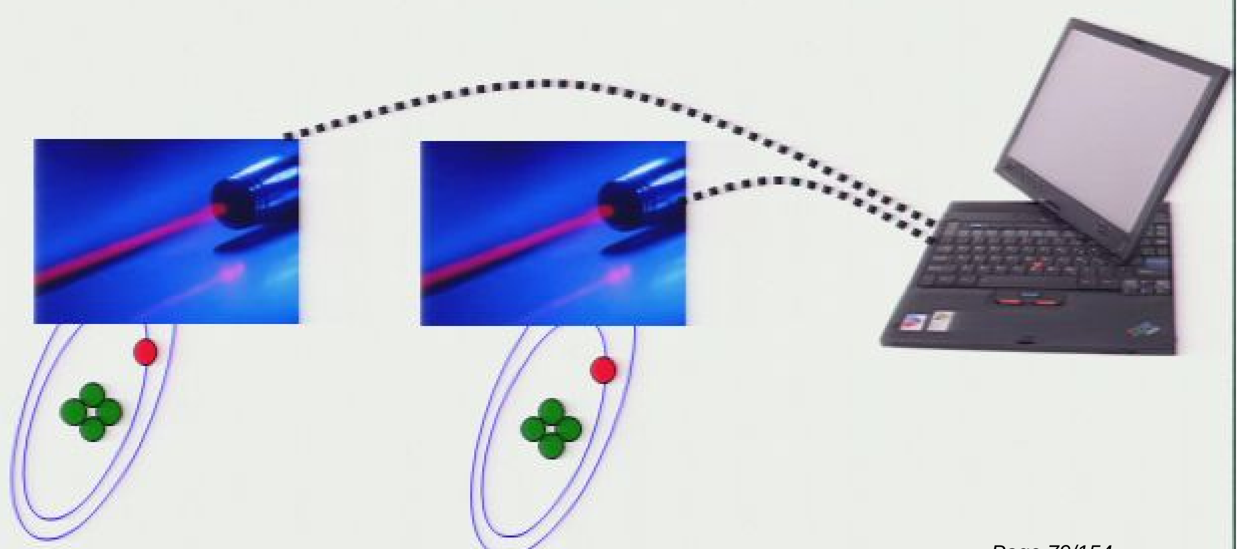

Example 2

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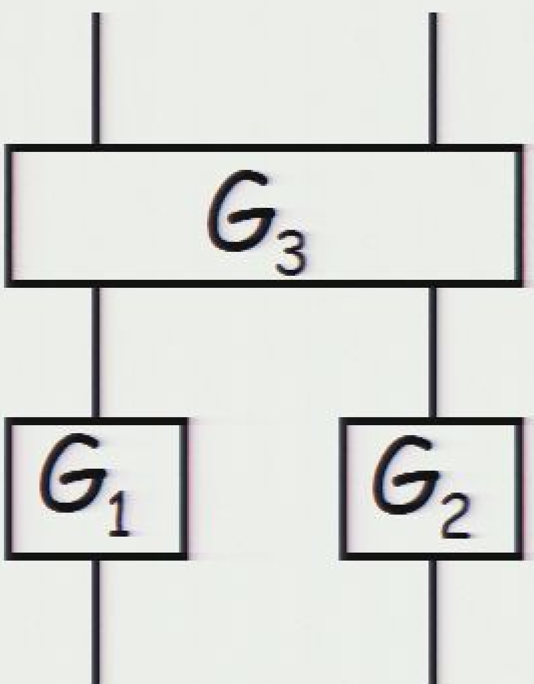

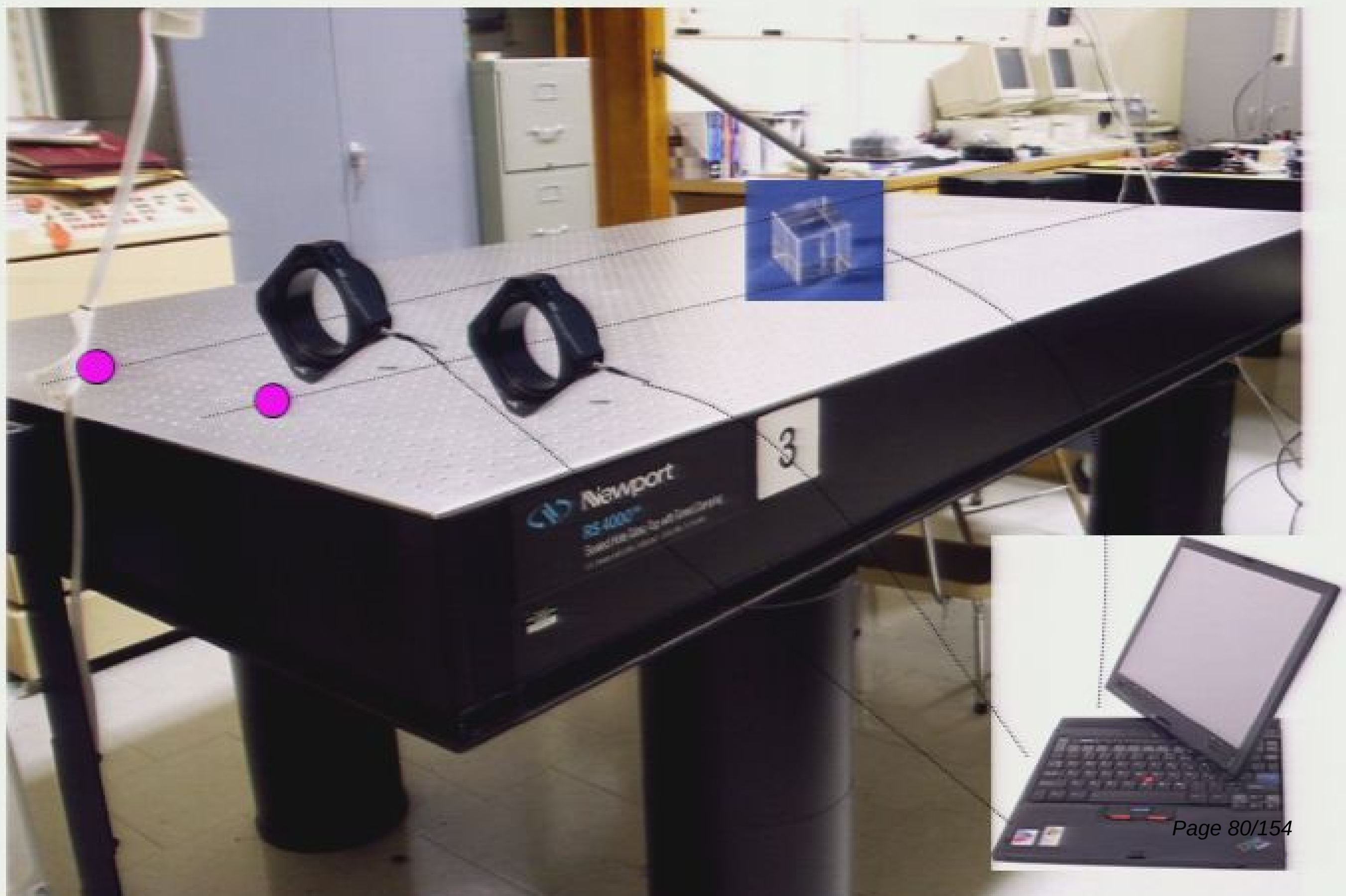

Another major challenge

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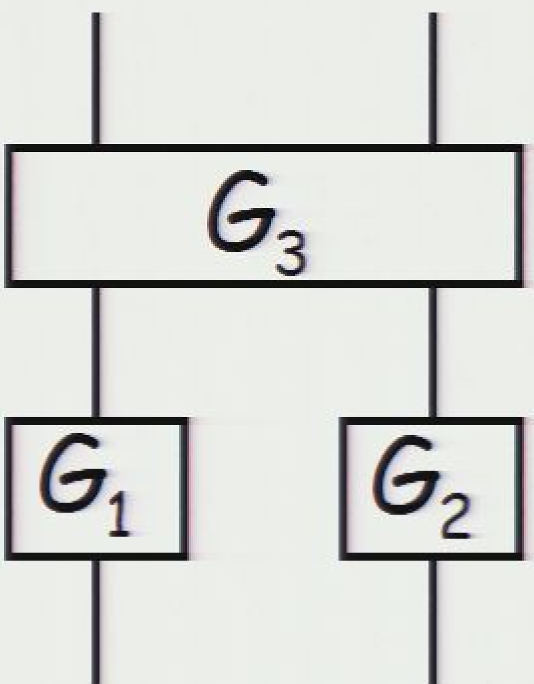

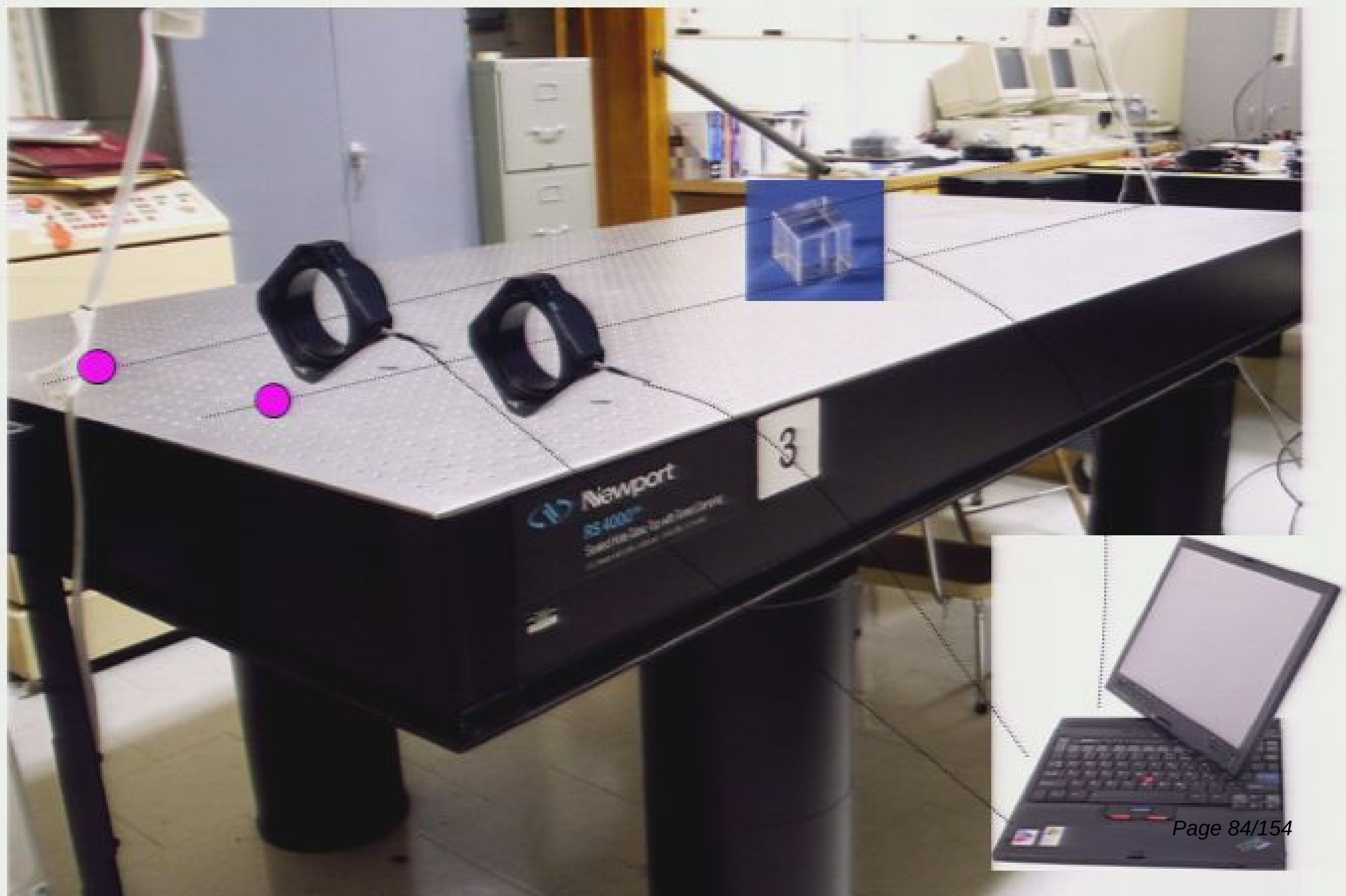

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Hint: Every circuit we would wish to run needs to also be part of a test.

example

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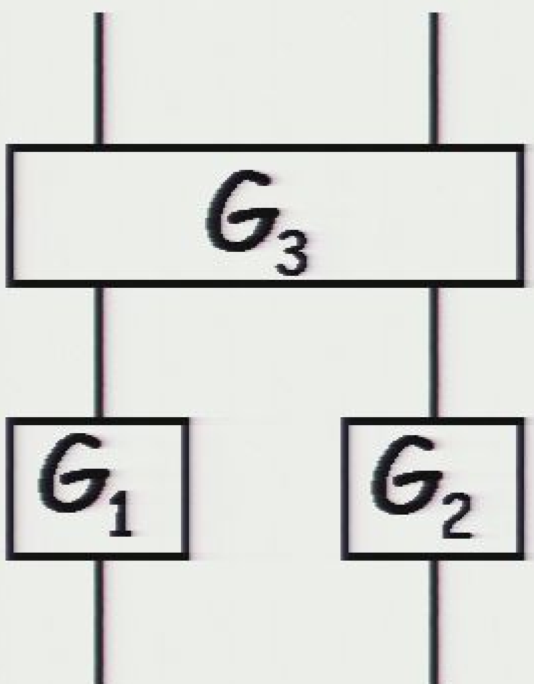
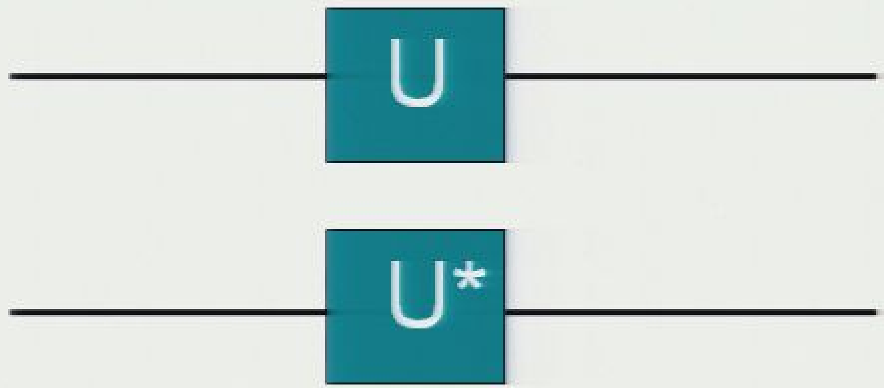


Property of EPR pairs



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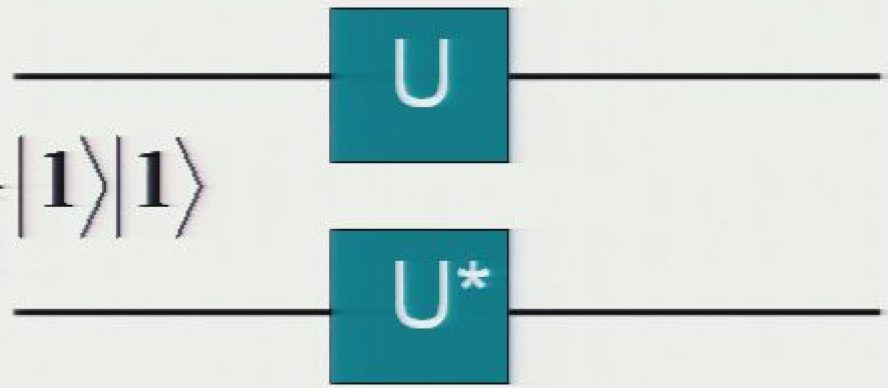

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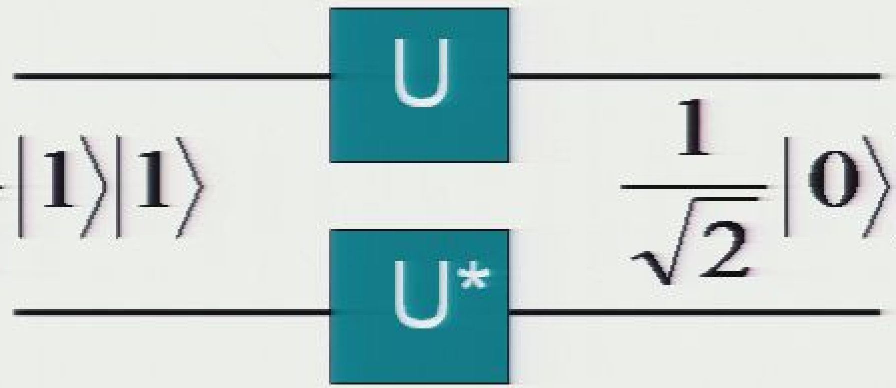

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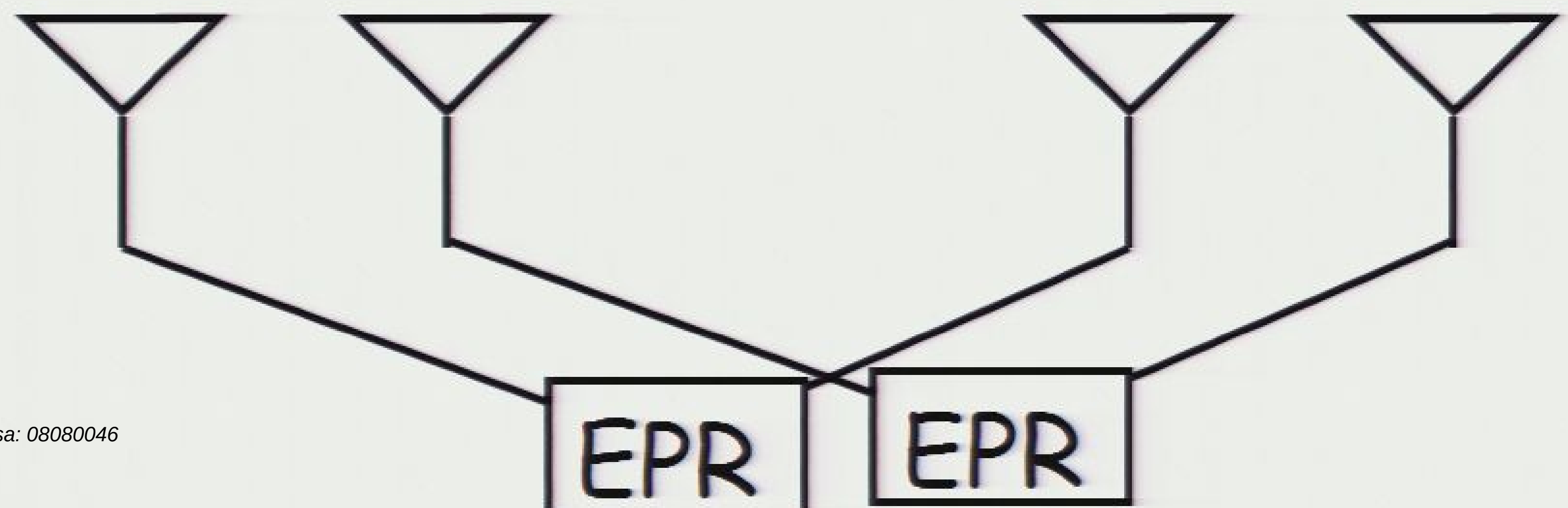

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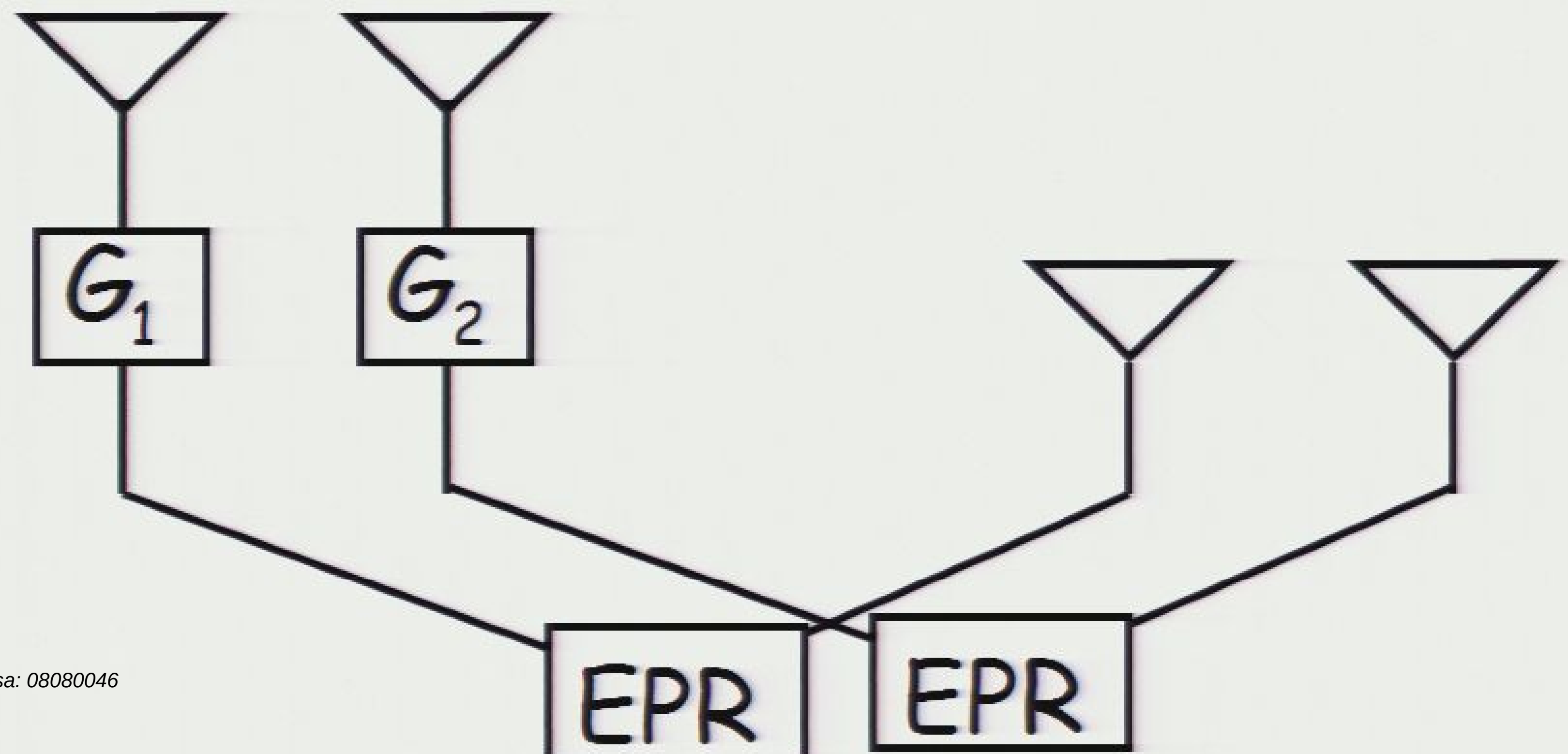

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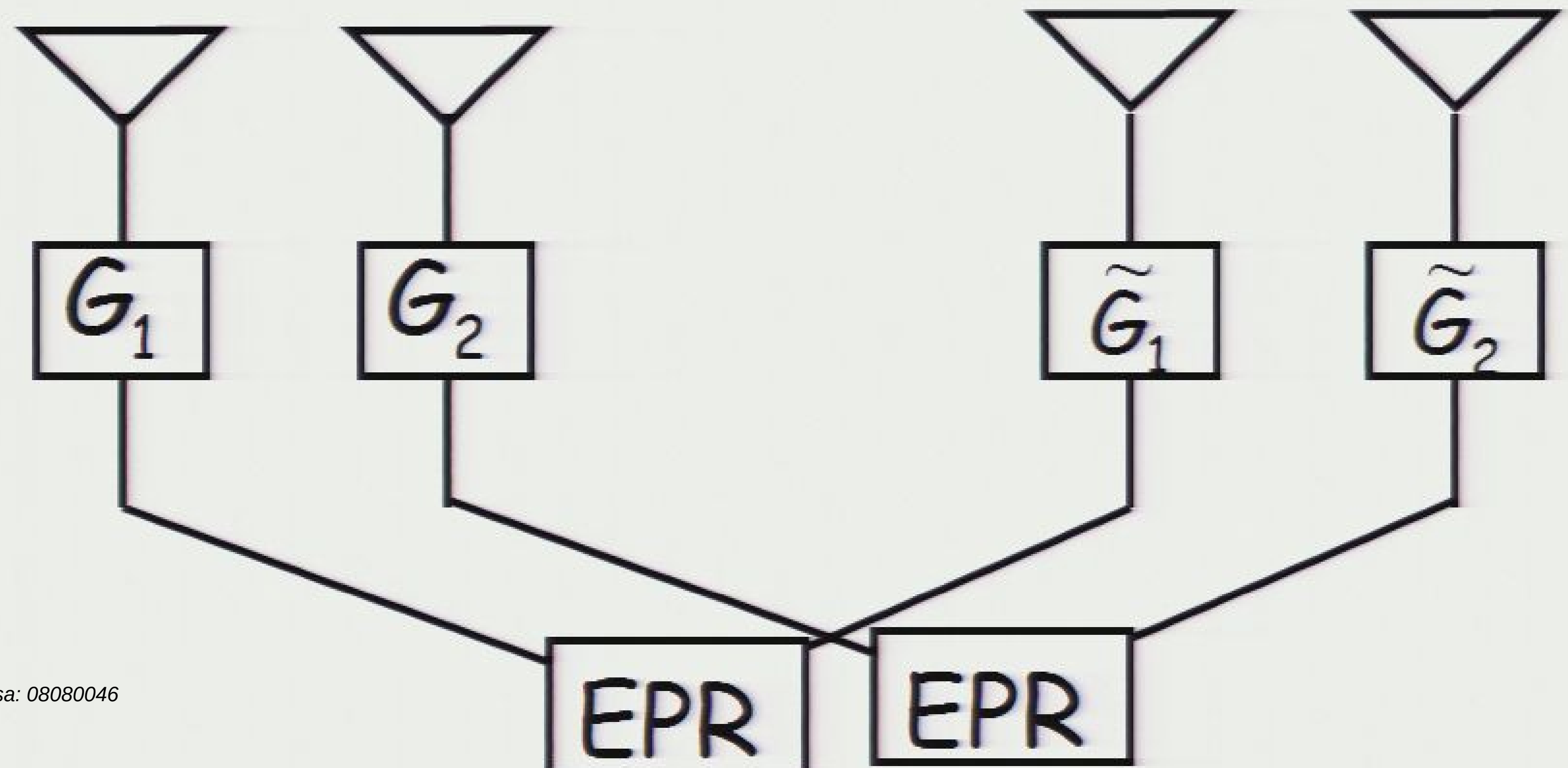

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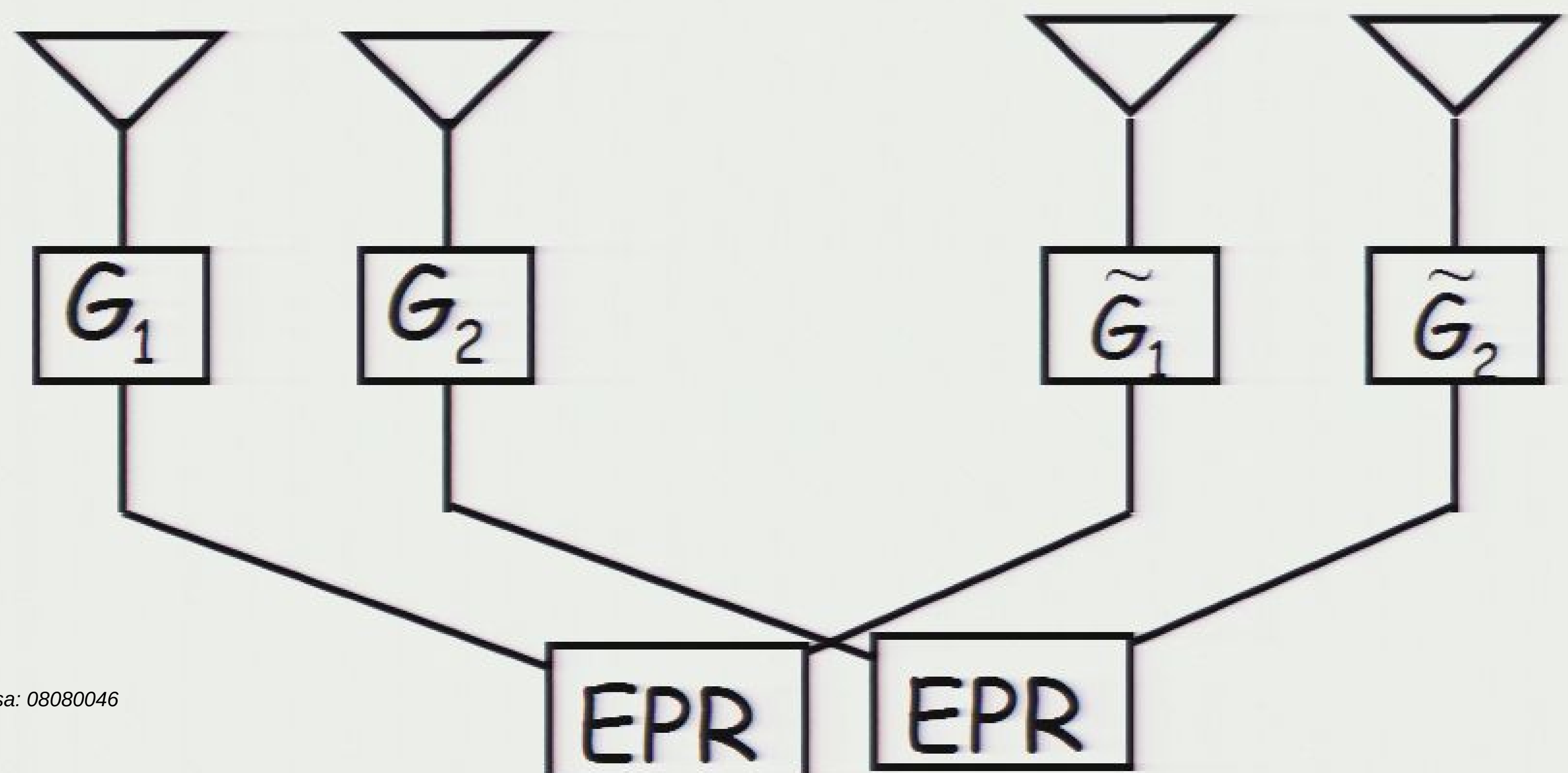
If $\widetilde{G}_1 = G_1^*$*, then this should recreate two EPR pairs.*



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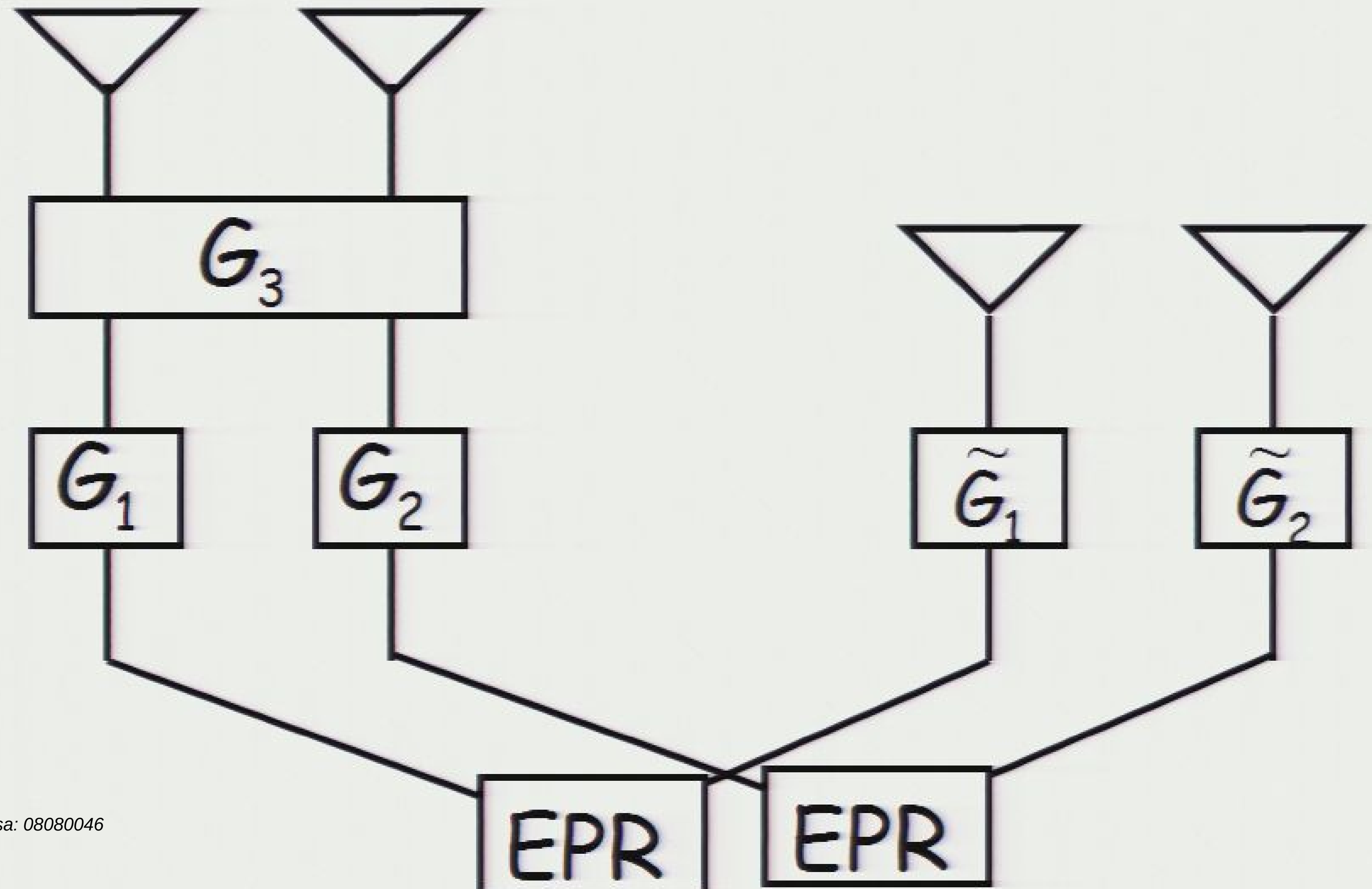

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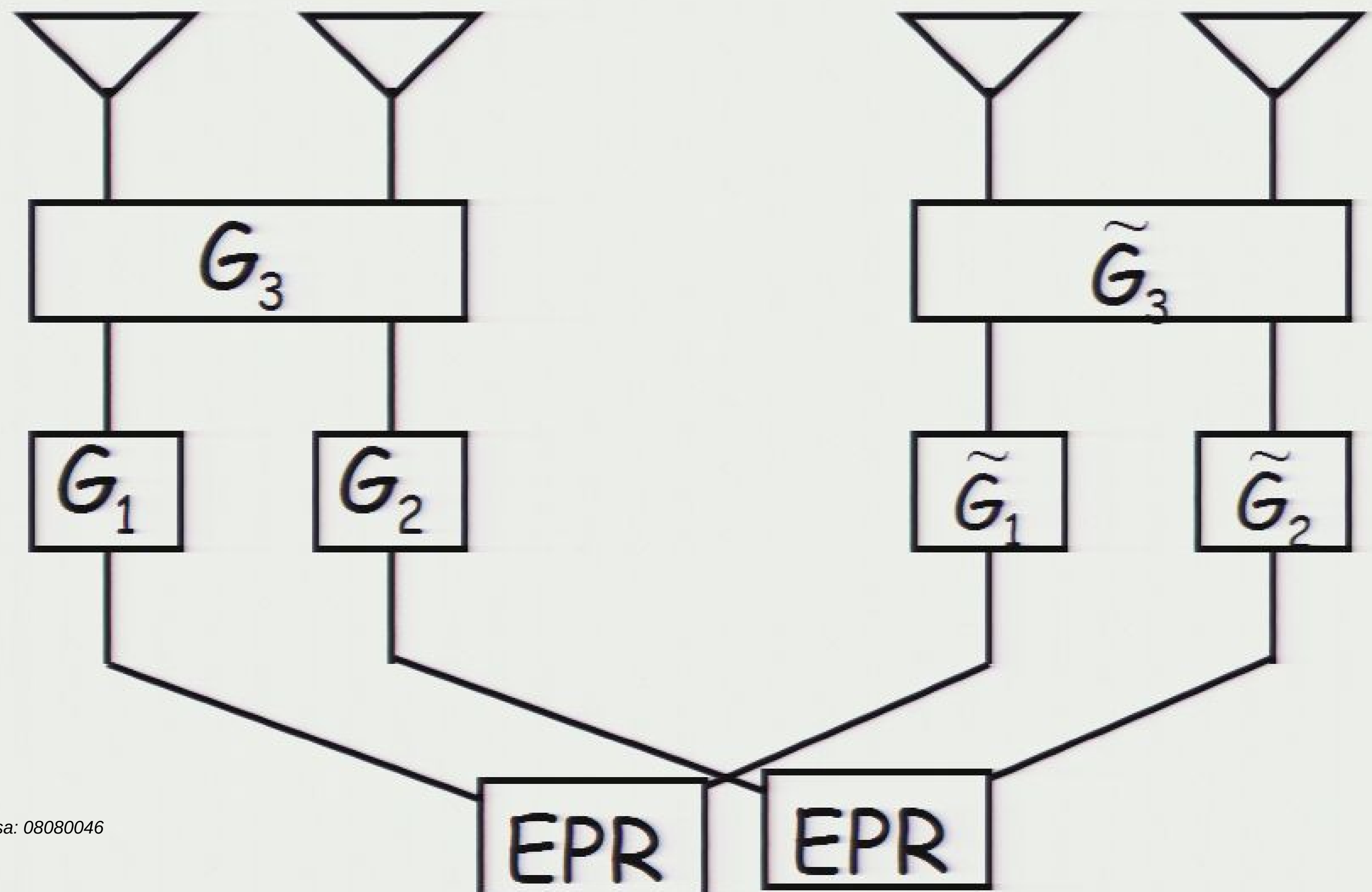

Some technical points

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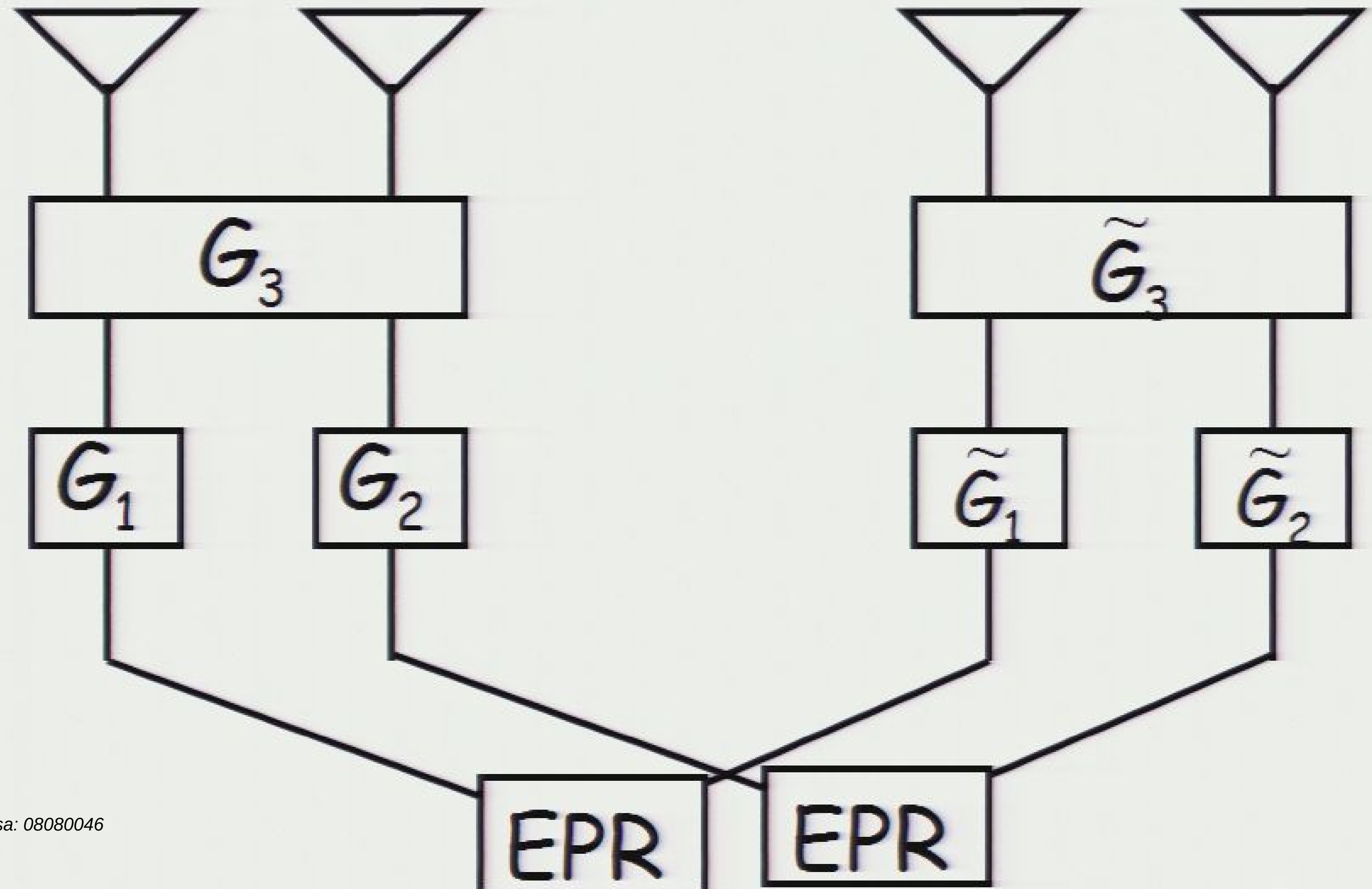

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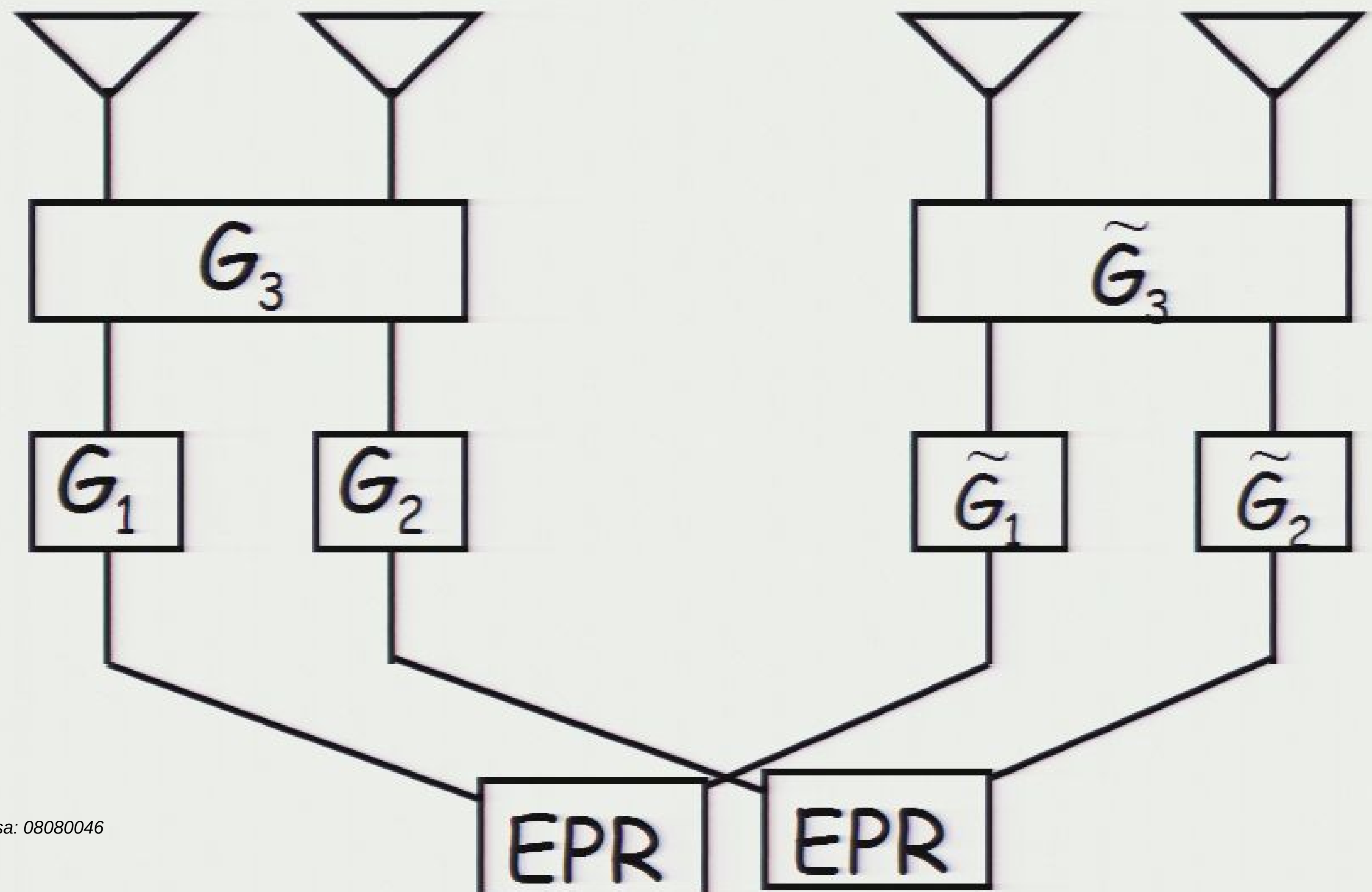

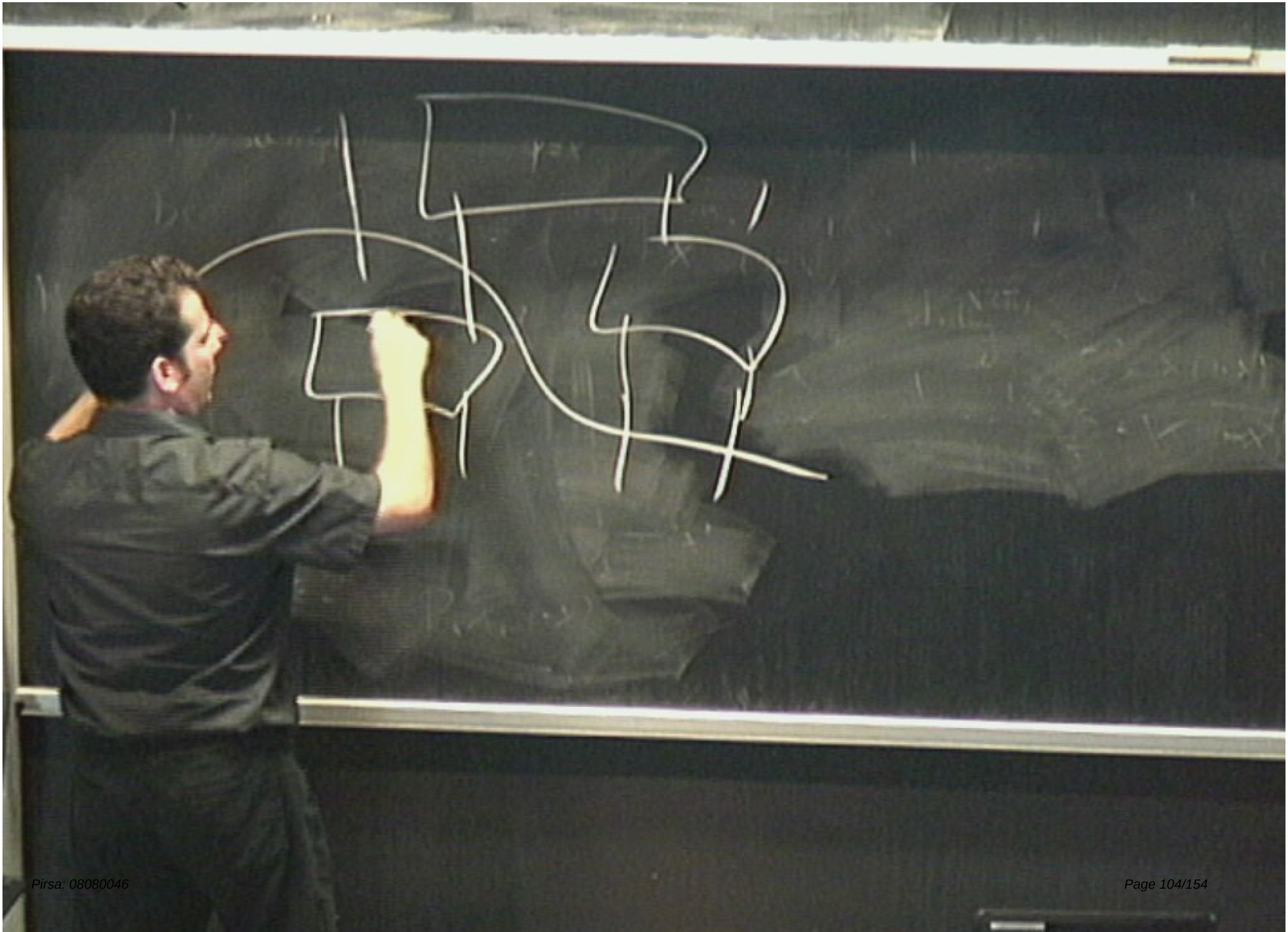

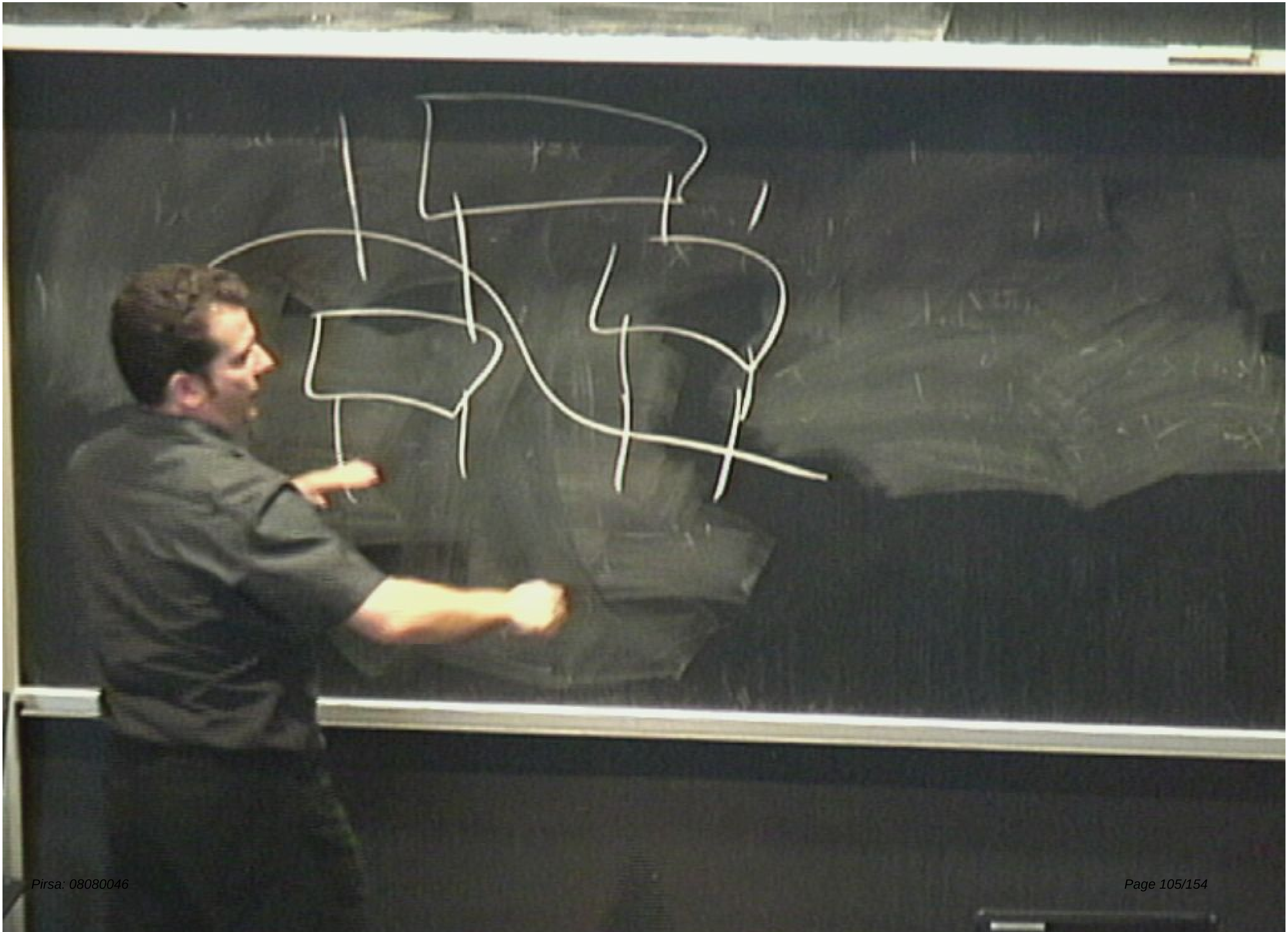

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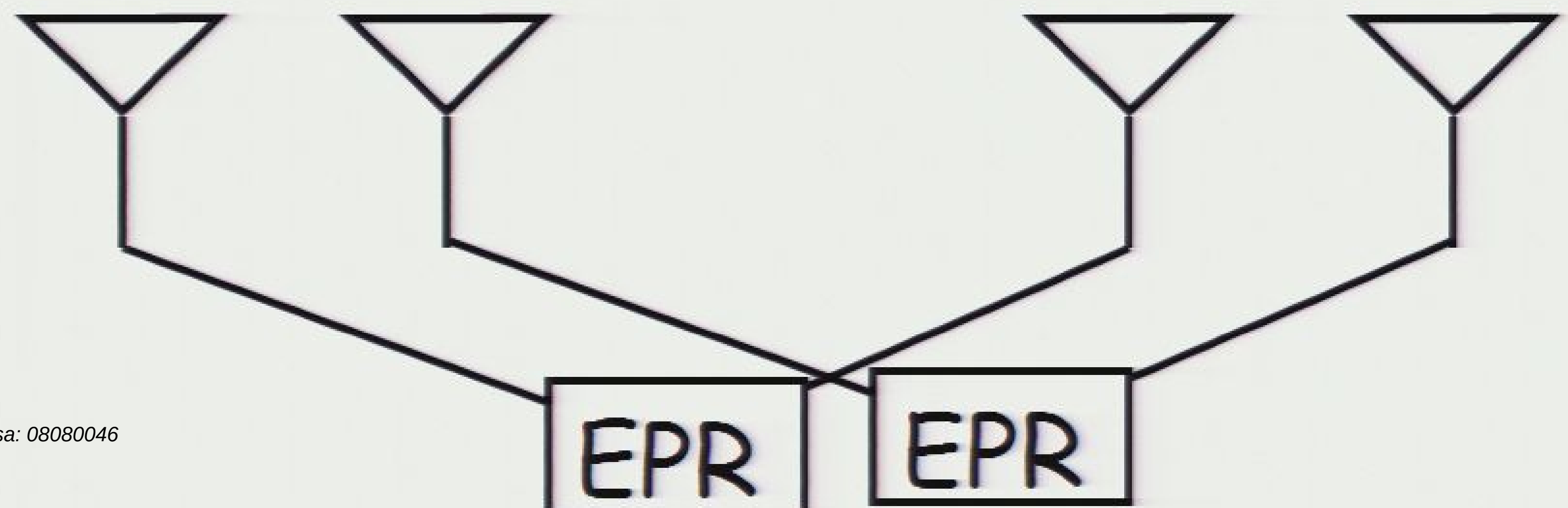

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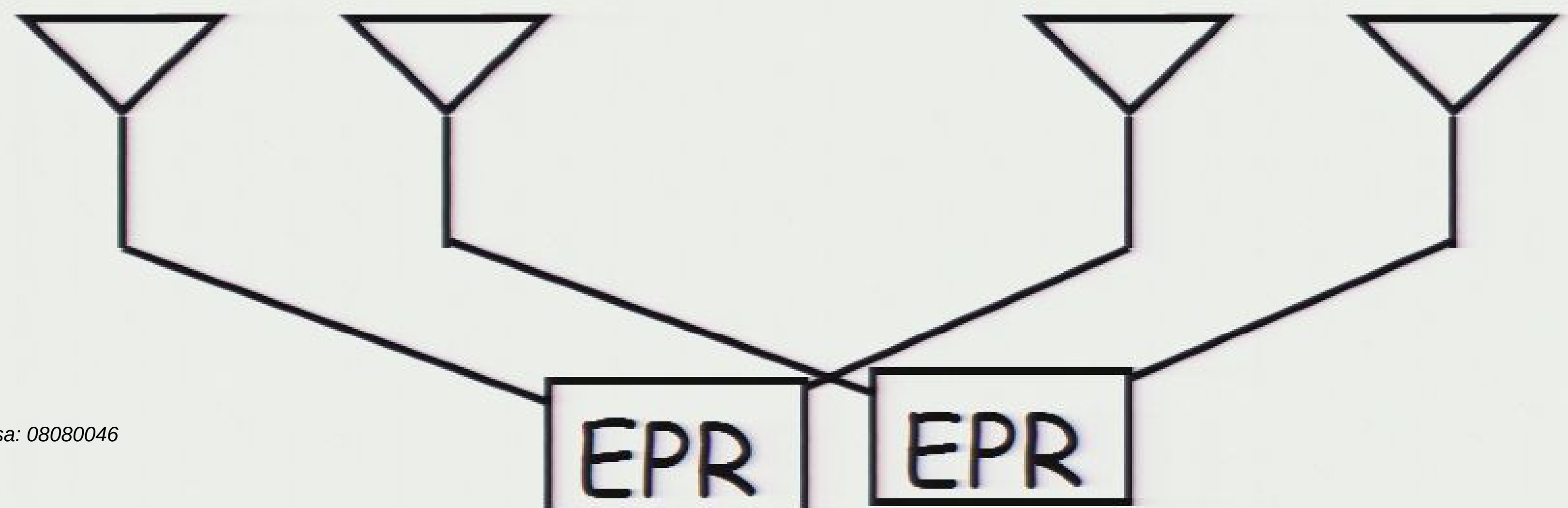

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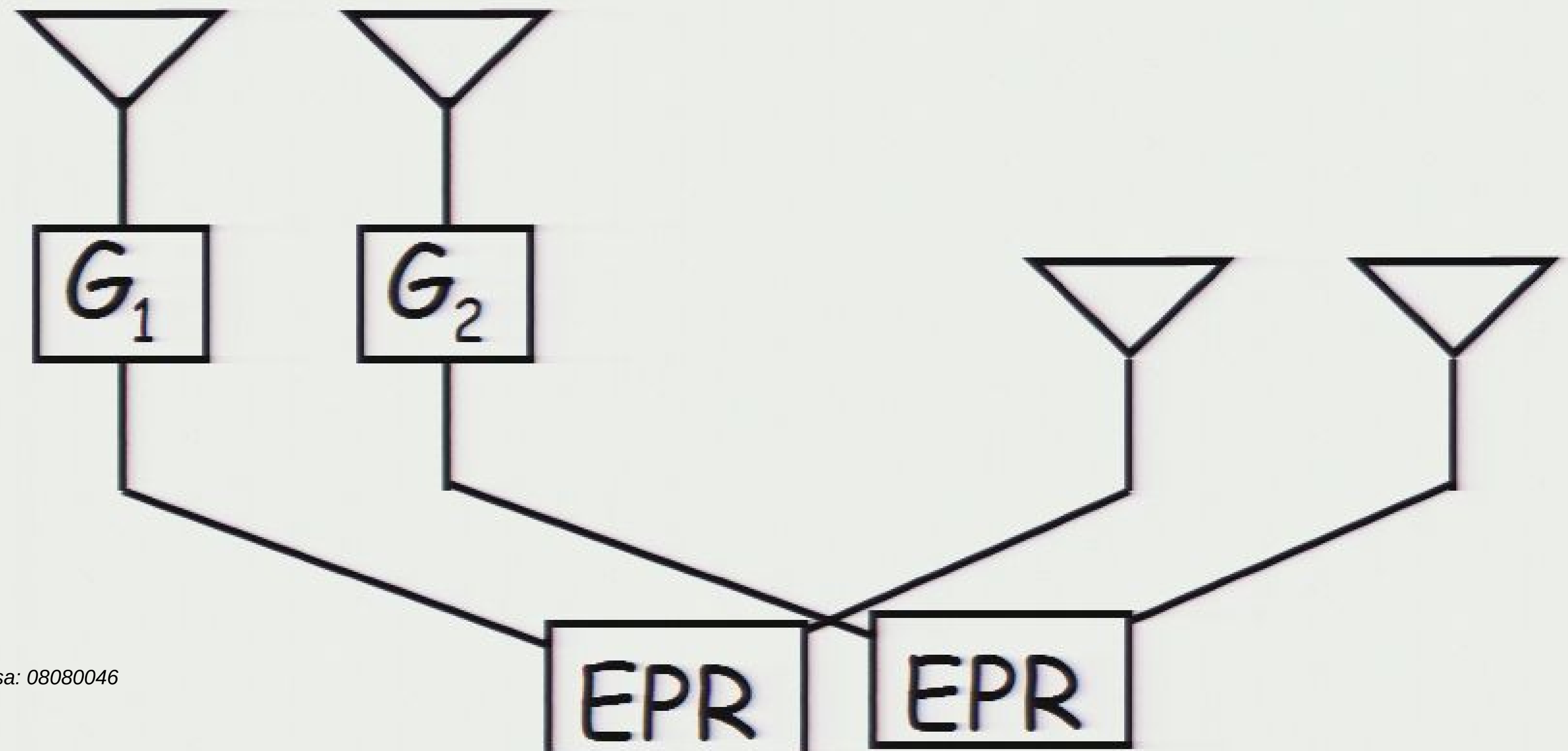

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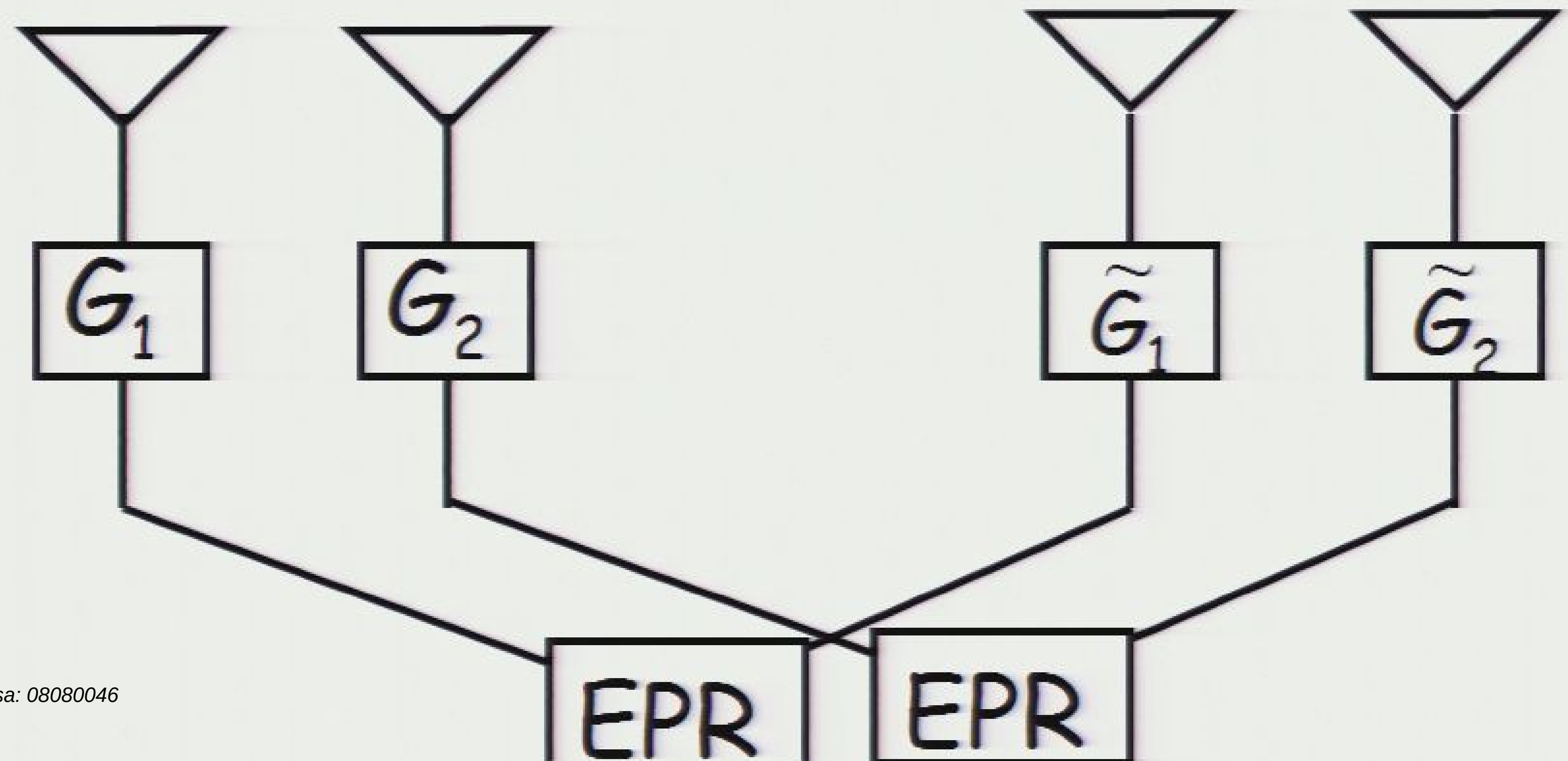

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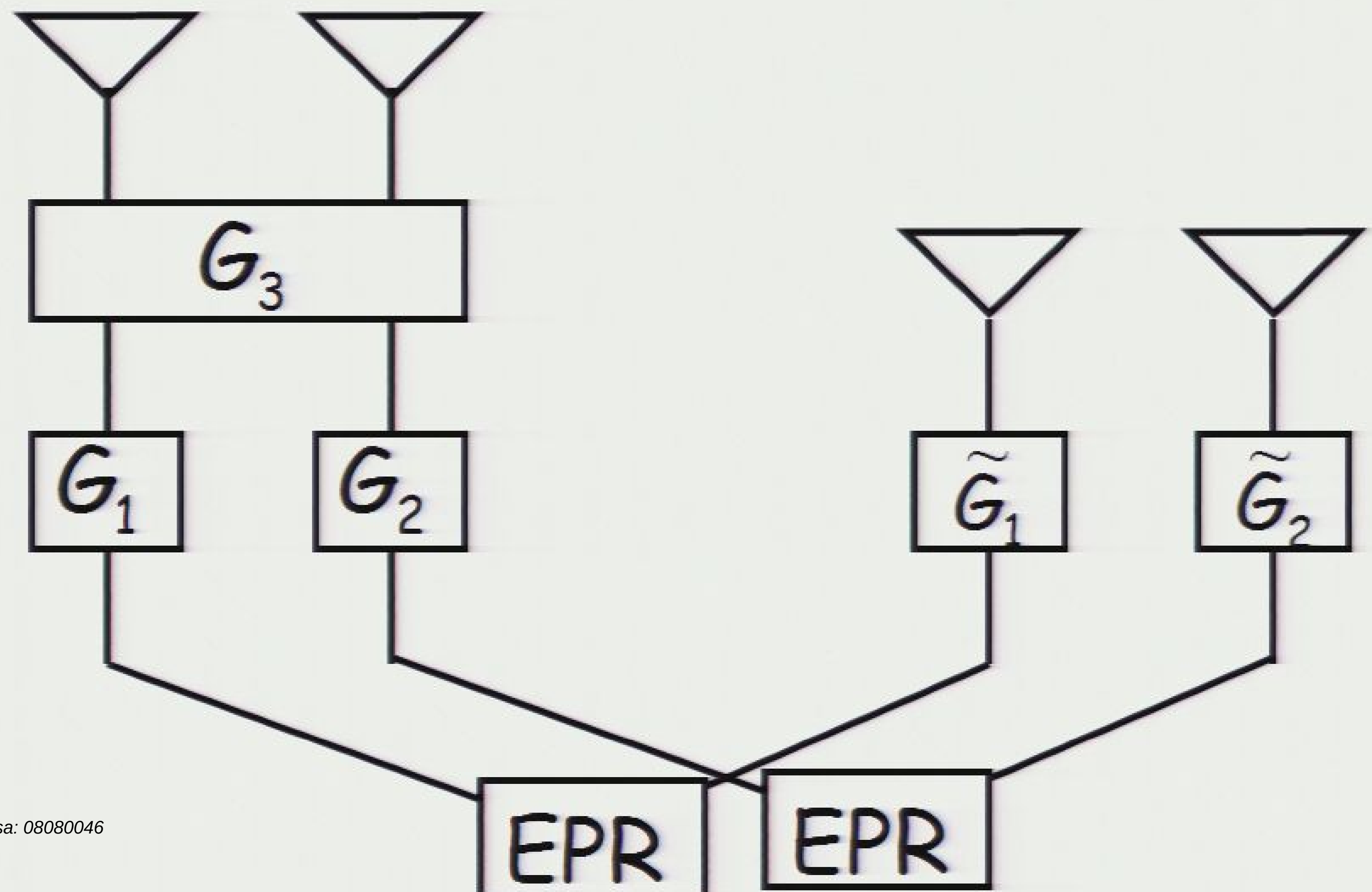

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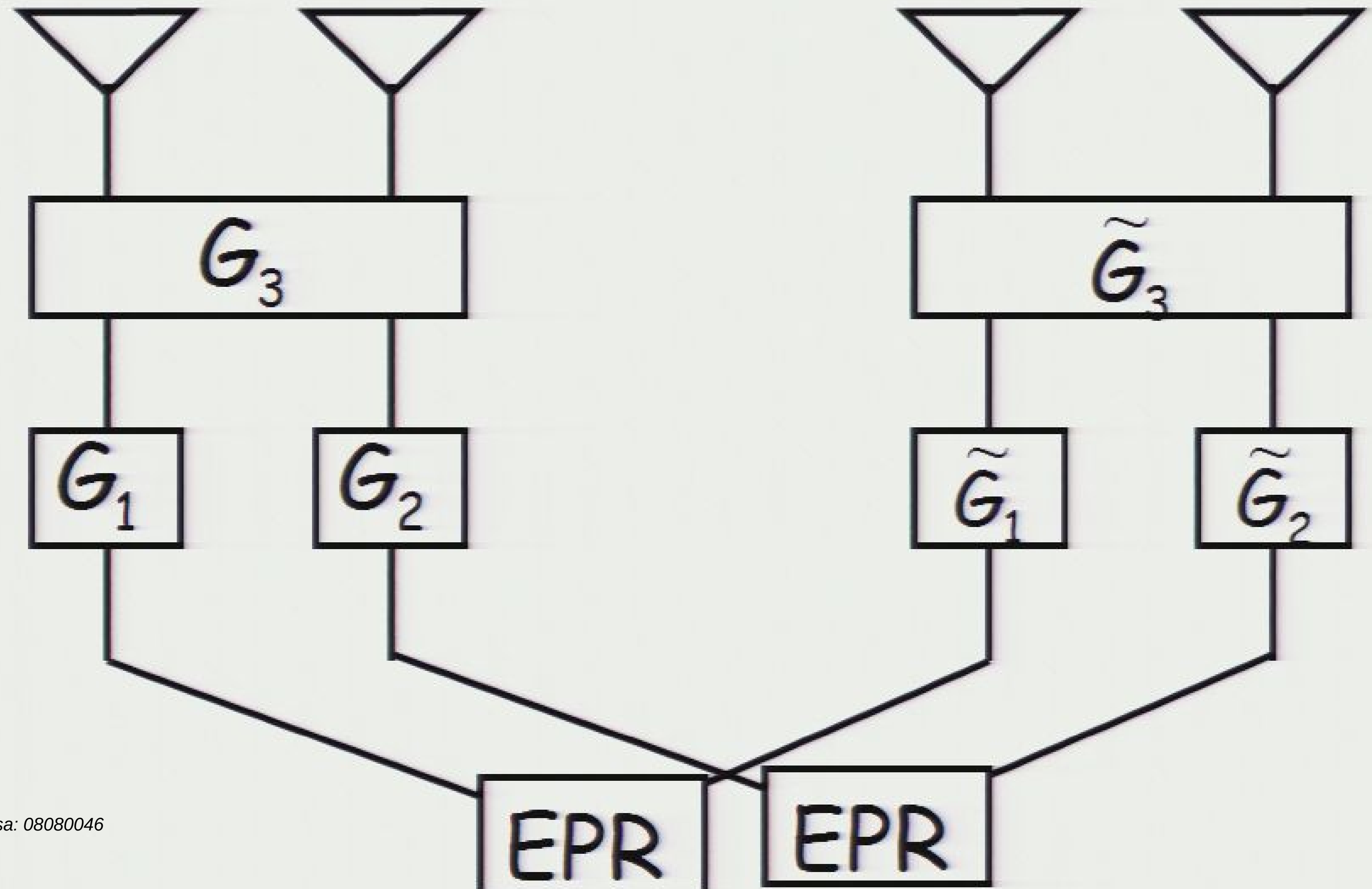

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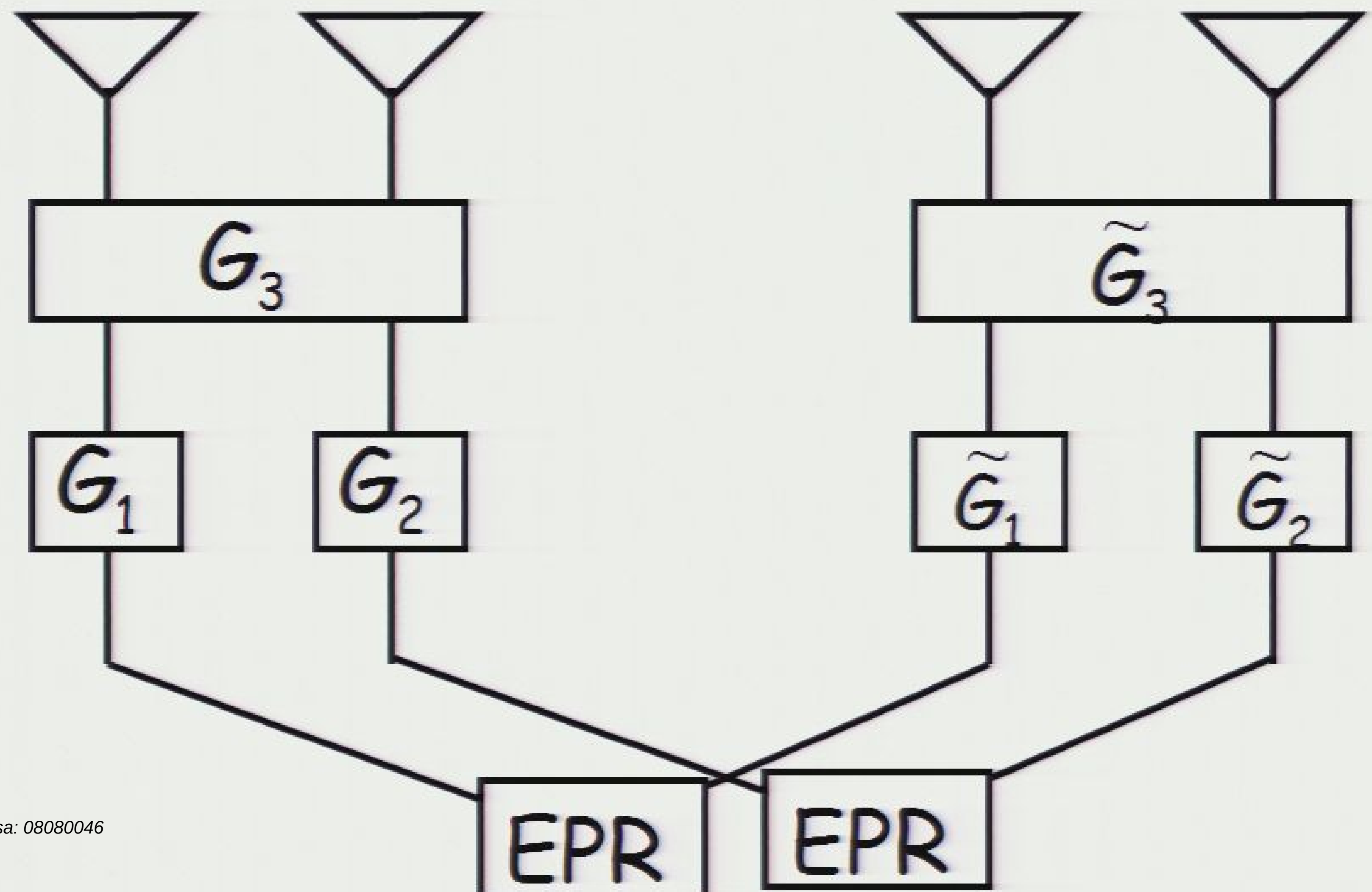

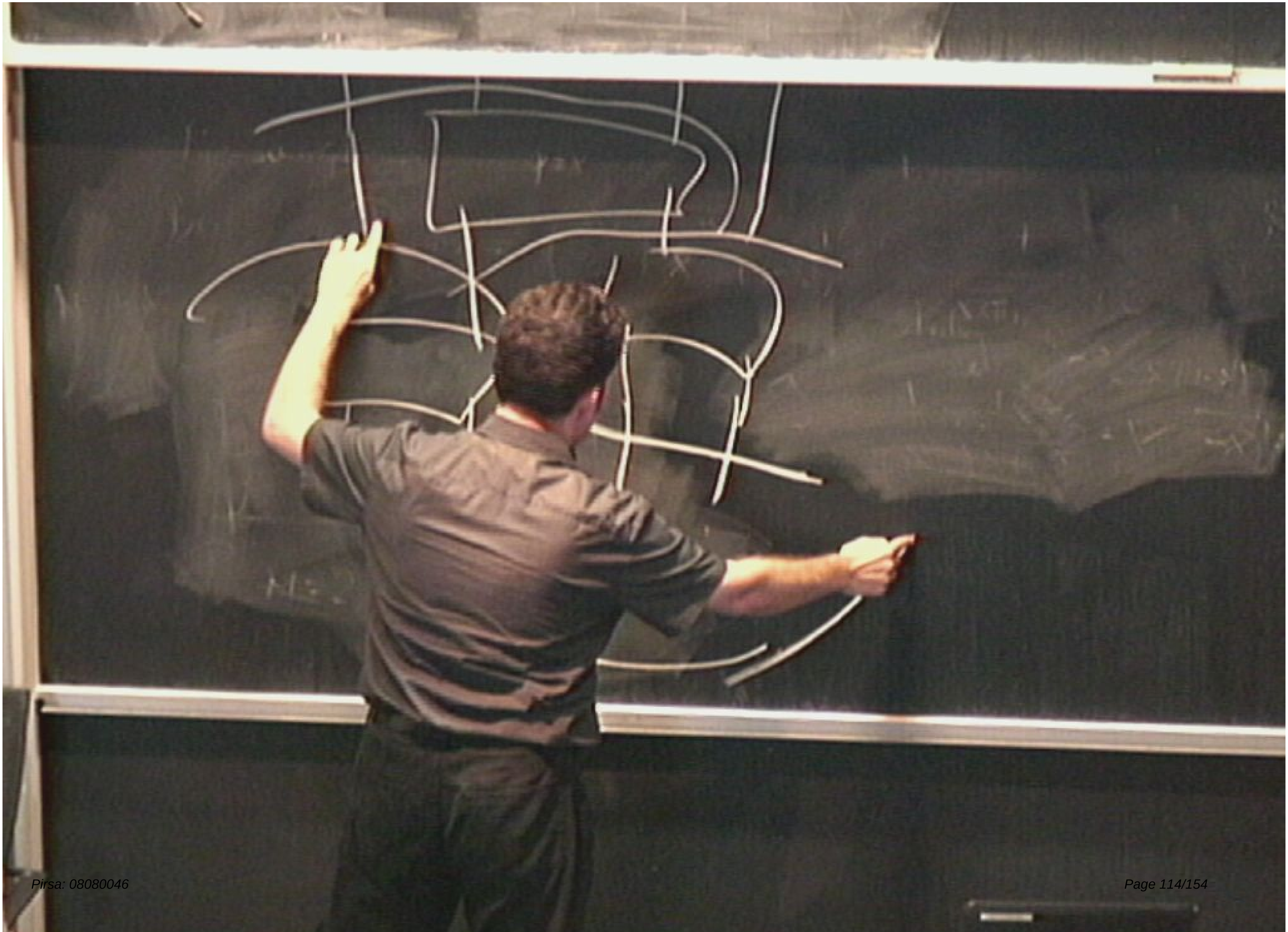

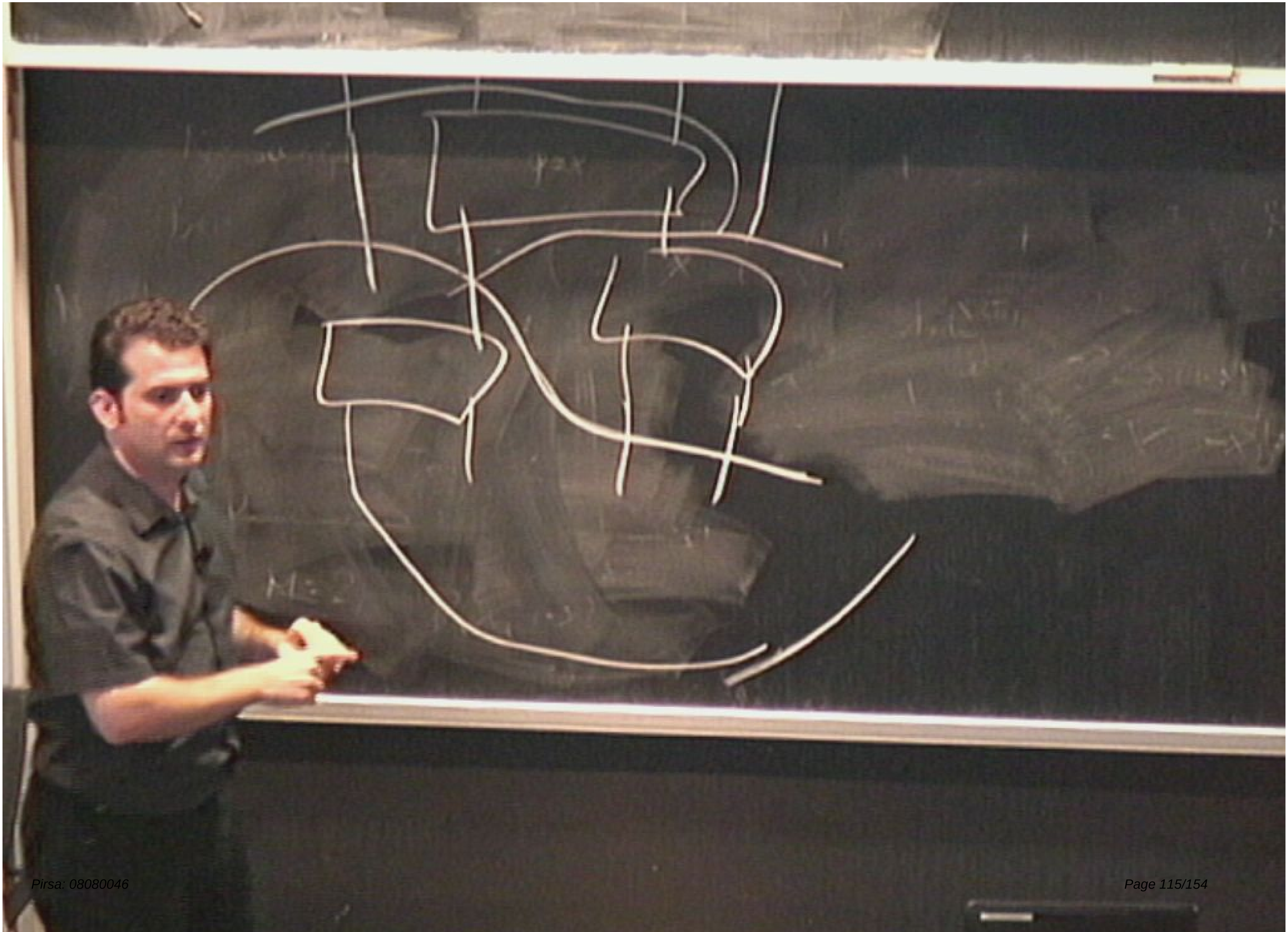

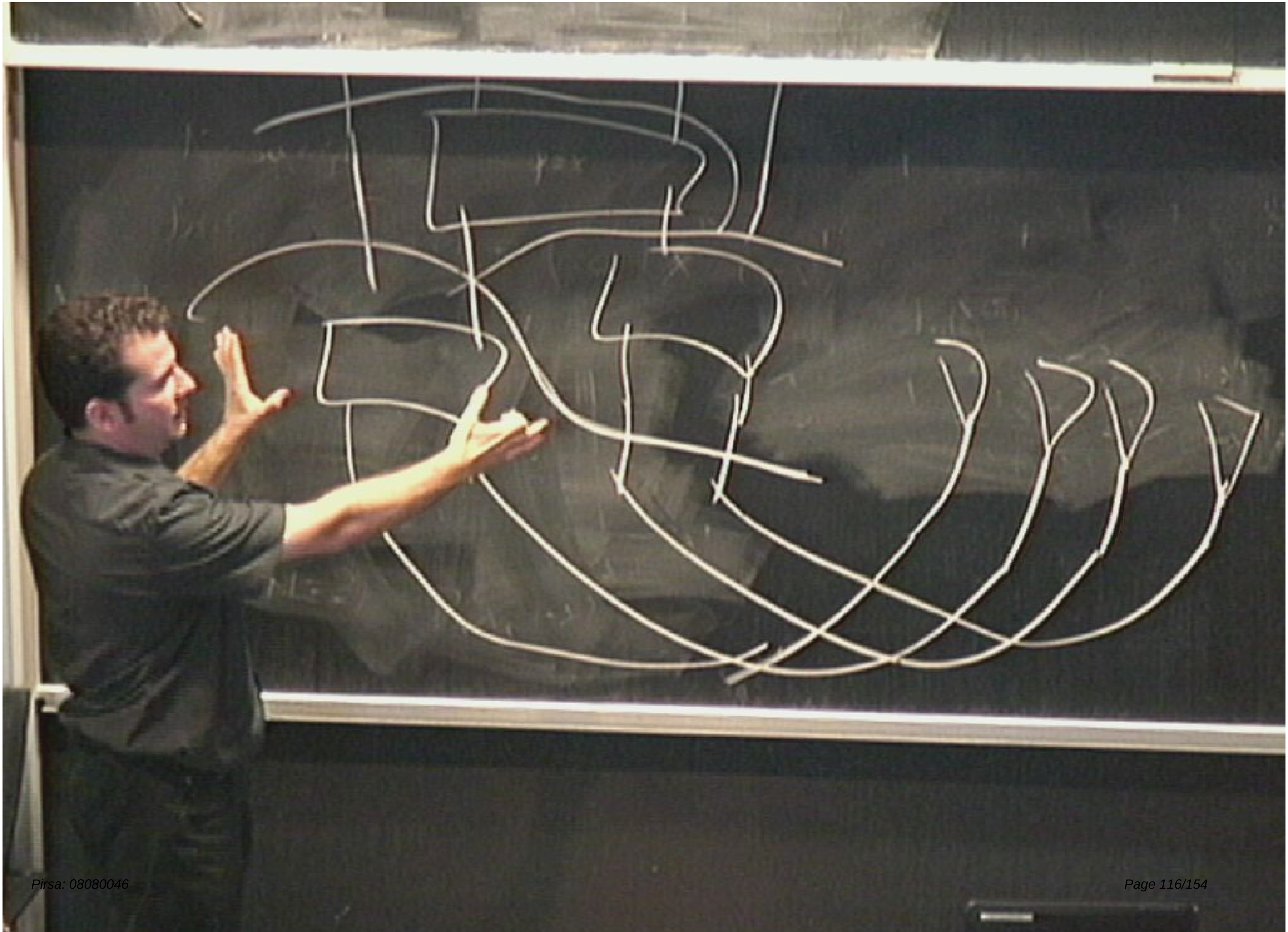

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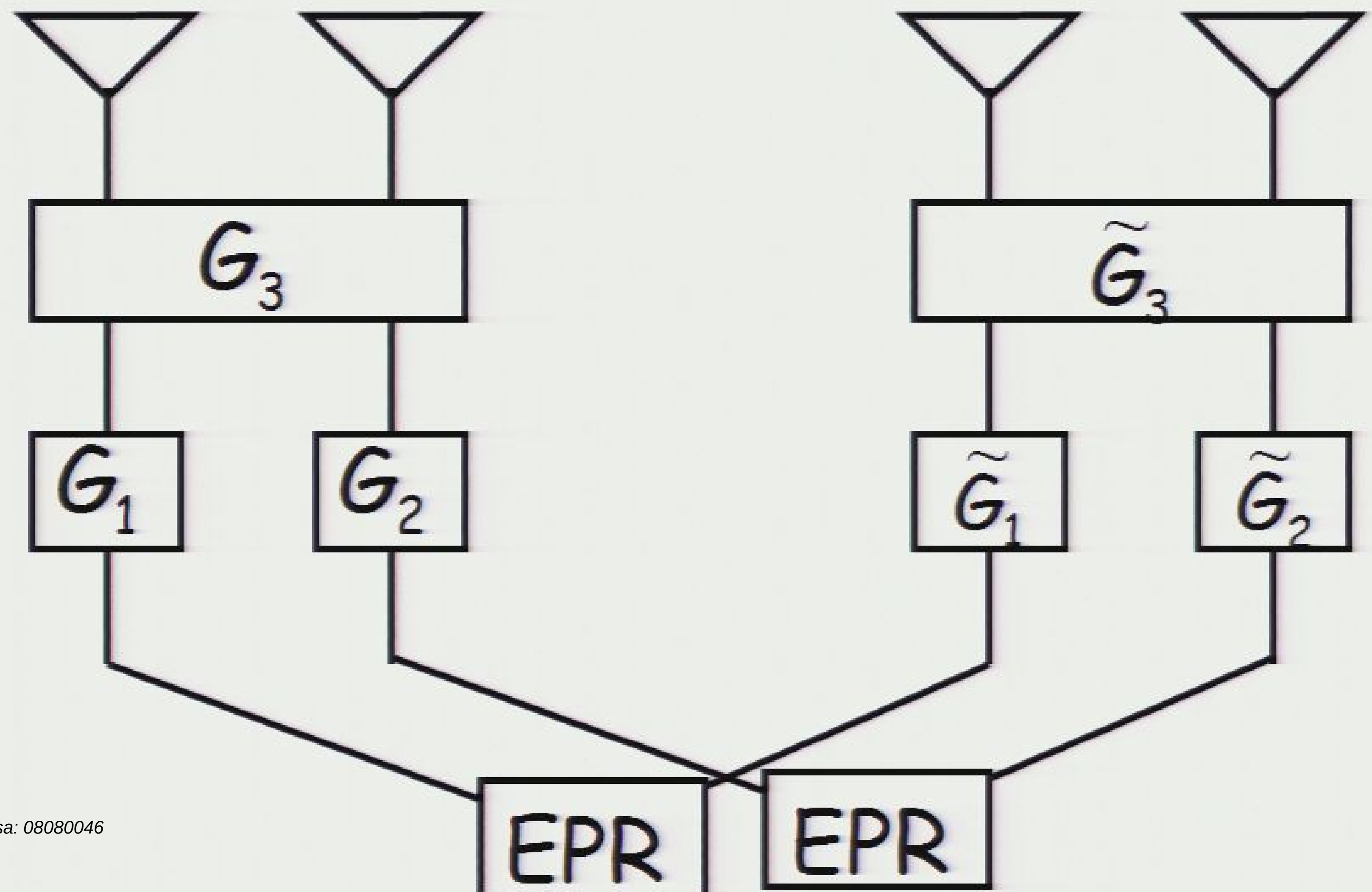

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complex bit can be simulated by 2 real bits (see .g. Rudolph and Grover quant-ph/0210187; non-ocal version given in a few minutes). But the two ystems are not "equivalent" according to our otion of equivalence. E.g. inner products are not reserved

Other technical points

Our tools include defining a notion of "simulation" and "equivalence".

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Under the right conditions, simulation implies equivalence, and we are able to get our main results.

Precise statement of our main result

Let $T^1, T^2, \cdots, T^k \in U(2^n)$ *(acting on a constant number of qubits each)*

$x \in \{0,1\}^n, \varepsilon > 0, \gamma > 0$

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If $\mathrm{CircuitTest}(T^1, T^2, \cdots, T^k, x, \varepsilon, \gamma)$ *accepts, then with probability* $1 - O(\gamma)$ *the outcome probability distribution of the circuit is at total variation distance* $O((k+n)\varepsilon^{1/8})$ *from the distribution that comes from the measurement of* $T^k T^{k-1} \cdots T^2 T^1 |x\rangle$ *in the computational basis.*

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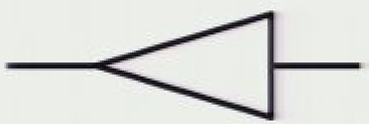

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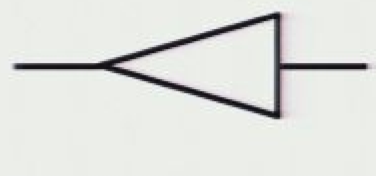

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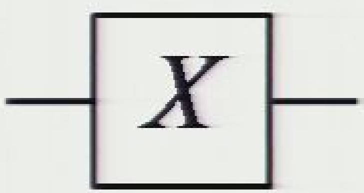

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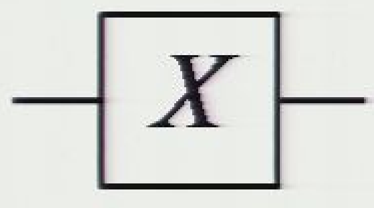

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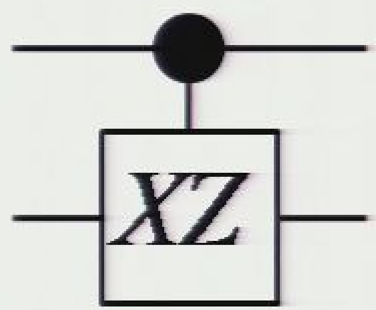

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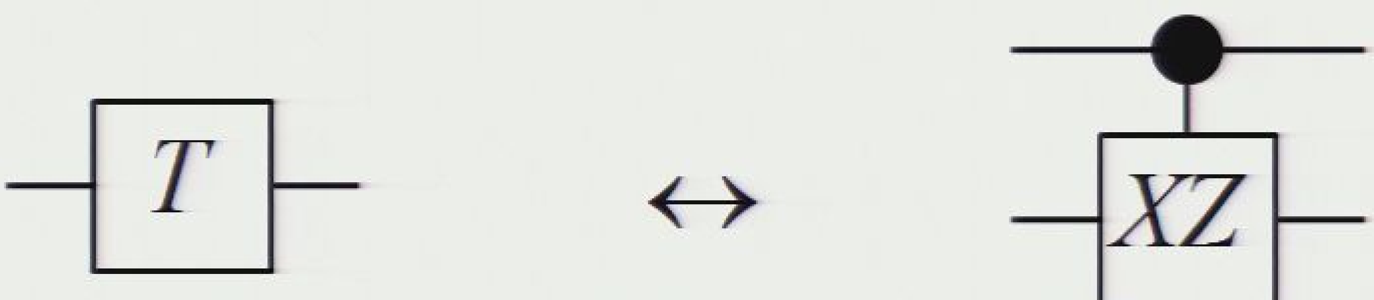

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Can we get around this problem?

A “local” conspiracy (with M. McKague, also independently found by Pironio/Navascues/etc.)

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Ve replace the extra qubit with n qubits in the ntangled state:

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What does this conspiracy mean?

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- *Apply these techniques to actual experiments (e.g. with poor photon detectors). Modify as needed.*

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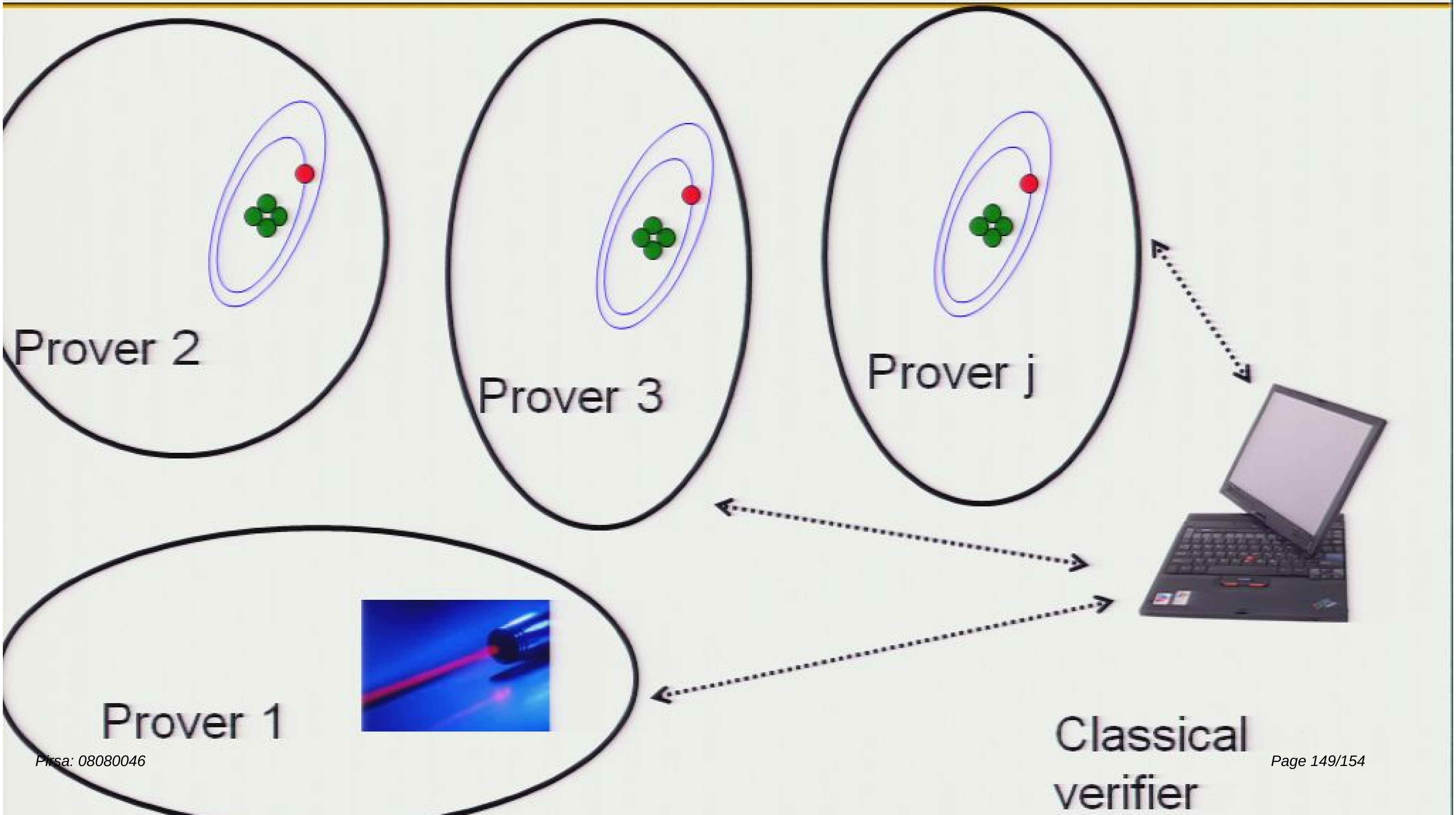
Multi-prover interactive proof paradigm



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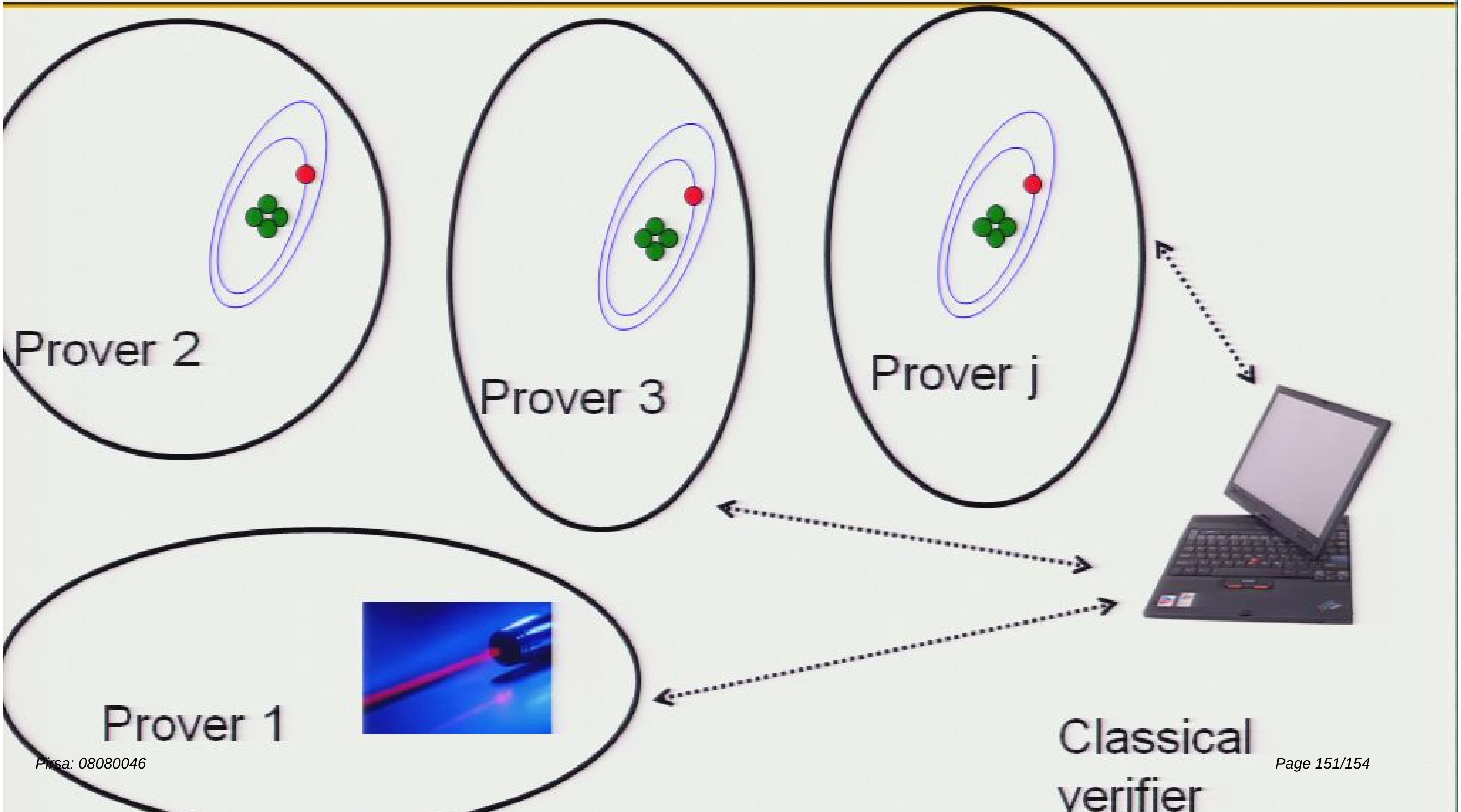

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