Introduction to Wave Interference Networks

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***Abstract*—We will observe time domain properties (delays, excitement locations, time functions at locations, velocities) to understand communication principles in nerve networks. We will call the abstraction *"Wave Interference Network"* (IN). By contrast to Artificial Neural Nets (ANN) all signals on wires of IN have *distributed (inherent) delays*. IN have no clocks. States are distributed. The term "interference" means an universal superimposition or interaction of mostly non-periodic, spiking and delayed time functions. The paper addresses questions of a general understanding of "pictures of thought", sound maps or movement maps [10], [9], [12], [5], [6], [13], [11], [8], [15], [14], [4], [7] in nerve systems in the same way, as it addresses technical applications (Acoustics, Radar, Sonar, lens systems, feedback controls, GPS, cellular networks, convolution codes, integral transformations). We try to give an impression of the high potential of signal interference in nerves and in circuit theory. Analyzing the spherical flow of *time functions*, we find them to be *waves*. IN create an *abstract wave theory without materialistic background*. This background gives the possibility to synchronize knowledge of different scientific fields. It has potential to combine parts of wave optics, neural nets, acoustics, filter theory, control theory, electron-physics, cellular automaton and neuro-science under one physical roof. The IN-approach creates a high potential for education of students if introduced as basic lecture.**

> "The question, how the nervous system creates representations of its environment has fascinated philosophers and scientists since mankind began to reflect on its own nature." Wolf Singer, 1993

I. HISTORY OF IN

End of the 80th mankind had a lot of knowledge about artificial "neural" nets (ANNs), lots of works were done about learning nets, oscillatory nets or spatio-temporal maps, about holography or coherence. The output map of such networks represents in nerve like parametrization the input map - if ever existent. By coincidence in September 1992 I found a general problem of ANN: If we suppose geometrically small impulses that flow slowly through such nets, it is *possible* to get *non-mirrored* output presentations (interference integrals) that correspond to input maps only, if the delay structure of the net is *artificial* (state machine abstraction). Like optical lens systems neural nets can only produce *mirrored* projections for inherent communication. 1993 I tried to find any mirrored map in neuro-computing literature, but failed. So I wrote the book [15]. Parallel the biologist Mark Konishi (Caltech) published a paper [19] about the same subject, remembering a forgotten work of his teacher Jeffress [17], where Jeffress discussed a part of the nerve network of an barn owl as interference system.

My inspiration in 1993 was influenced by multi-channel Radar-systems for cars. I found, that *continuously running time* in such systems can only produce *mirrored maps* with additional hints like *axial-near sharpness* known from optics. To get high-quality *non-mirrored images*, we need time reversal algorithms, later used as 'mask algorithm' for first acoustic images and films [3], [24]. This was the birthplace of the so called *Acoustic Camera* [25] technology[1].

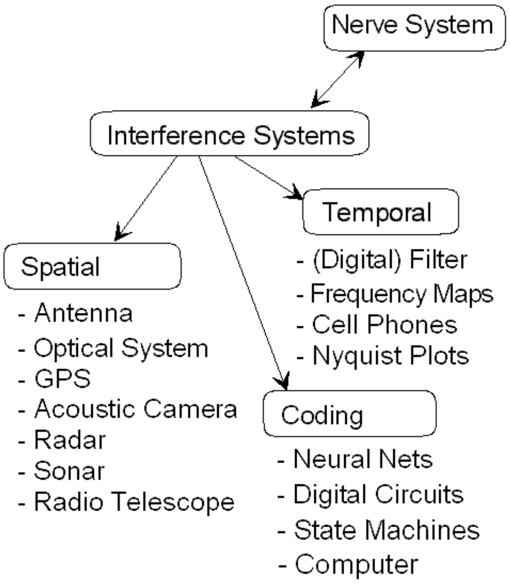

Figure 1. Types of interference networks

II. GEOMETRICAL WAVELENGTH IN NERVE NETS

Limited velocity v of nerve pulses in the range µm/s ... m/s supposed [13], any small pulse peak with a duration τ causes a *geometrical wave length* λ in the range between micrometer and meter:

$$\lambda = v\tau \tag{1}$$

The geometrical length of a pulse can be very short in comparison to the size of a neuron, compare Table 1.

Interference nets can be compared with cross-roads: the probability that cars (~ pulses) coming from different roads (~ dendrites) crashes on the crossing (~ soma) is as higher, as smaller is the distances between the cars, or as longer are the cars, or as slower (!) is the speed. Static signals (EPSP,

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[1] The paper has nothing to do with electric or magnetic or acoustic fields: we examine waves and wave field integrals of time functions, *without of any materialistic background.*

IPSP...) at logic circuits (soma) are comparable to infinite long trains crashing statically at the crossing. In nerves with pulse/pause ratios *R* ~ 1:10 to 1:10.000 the "crash probability" for excitement is very small. It lays in the same range. At the other side, any average pyramidal neuron has a number of *n* ~ 7400 synapses. So the average probability *P* for any crash is nearly *P* = *nR* = 1.

What happens in such nets? Which kind of signal processing occurs there? Instead of calculating probabilities we have to ask for "crash" places in the whole net. We have to follow a single impulse or signal over the whole network, hoping it meets his double(s) at a certain place - we have to look for (discrete) interference locations of signals, for discrete *pulse wave interferences within the whole network.*

Table 1: Velocity and pulse wavelenght in nerve system

nerve velocity in m/s	0.5 - 2.0	12 - 30	30 - 70	70 - 120
fiber diameter in µm	0.4 - 1.2	2 - 5	6 - 12	12 - 20
length of a 0.1ms peak in mm (wavelength)	0.05 - 0.2	1.2 - 3	3 - 7	7 - 12
type by Erlanger/Gasser	C	Aδ	Aβ	Aα

Introducing this approach we find, that *nerve networks* (in opposite to neural nets) map the input pattern only *mirrored* to the output, comparable to optical lens systems. In September 1992 this idea was like a shock for me: It was not possible to find any scientific publication about a mirroring property in neuro-computing (ANN-) literature. The importance increased, as more such wave analogies lead in direction to optical projections. Like a interference circuit in nerve dimensions a simple, optical lens system mirrors the image. The next shock was, that I could not find anything about elementary wave conditions for optical projections, looking for abstract wave-conditions.

So the idea was born to investigate the field of "*discrete wave interference on distributed, wired nets*". Can a physical approach to neural nets (later called "*interference nets*") create a connection between wave physics (optical, acoustical) and neuro-computing?

III. CHARACTER OF IN

By contrast to "neural" networks (ANN) wires of IN all have individual delays. There is no global state abstraction and no global clock. Wires have velocities, delays and spatial information. The time functions flow on the wires with constant or variable speed, with or without attenuation. IN demand simulations in time domain. Choice of a rough time or space grid or improper use of time function parameters destroy the wave properties of an IN immediately! Spatial arrangements of bundles of wires, studied in [15], show the influence of geometrical changes to wave fronts on the bundle: "space codes behavior". It is necessary to define the delays in the space arrangement of each wire. In meaning of interference we use the term "discrete wave" instead of "signal" to manifest this property. We find following properties of IN:

- Nets consist of delaying wires and nodes
- Operations with time-functions occur only at nodes
- Each wire has an intrinsic delay only (wires are not electrical nodes!)
- No signal flow between nodes is without delay (integer or floating)
- Nodes carry time functions $f(t), f(t-T)$, wires shift only the delay *T*
- Attenuation (if necessary) occurs on wires or nodes (acoustic systems)
- Time functions are delayed between nodes *a* and *b* by $f(t-T)$, $T = T_b - T_a$
- Spatial node coordinates are possible $f(x, y, z)$ in spaces of homogeneous velocity (Acoustic Camera)
- *Time functions* appear like (abstract, discrete) *waves* in inhomogeneous or homogeneous space

Interference nets create an *abstract wave theory on inhomogeneous nets*[2].

IV. NUMERIC CALCULATIONS OF IN

Two ways of calculation are known.

1) *Bidirectional*: To calculate simple bidirectional interferences we use known matrix algebra, see [23]. We consider a time function $f(t-\tau)$ with parameter *t* and delayed by τ in numeric notation as vector of samples f_j; $F = f(t-\tau) = [f_1 - \tau, f_2 - \tau, ...f_n - \tau]$. Addition of time function vectors is analog to matrix algebra, $F_1 + F_2 + ... + F_n$. *Multiplication* of time functions is defined non-orthogonal as *scalar product* sample by sample, see [23], [3], [15]. For each *t* a new image appears.

Example 1. The numeric multiplication of *k* time functions having *n* samples each (without τ) is the scalar product

$$F_1 F_2 ... F_k = [f_{11}, ...f_{1n}] * [f_{21}, ...f_{2n}] * [f_{k1}, ...f_{kn}] \quad (2)$$

$$= [f_{11} f_{21} ... f_{k1}, f_{12} f_{22} ... f_{k2}, ... f_{1n} f_{2n} f_{kn}]. \quad (3)$$

2) *Mask algorithm*: For correct *calculations* of *spatial nets* with many waves, we have to read out the *delay structure* (also if inhomogeneous) of the net. The vector of delays defines a 'mask' shifted over the incomming time functions (channel data) [3].

Time function calculation is anytime algebraic in meaning of above equations. Only the sign of any timefunction can be opposite in relation to time flow direction (not in relation to spatial flow directions). Compare with the *mask algorithm* [3] used for first acoustic images and films (Acoustic Camera) for a better understanding.

Classic *convolution* (with a core $f(t) * g(\tau - t)$) is a source of confusion for IN. Convolution appears as interference of a

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[2] Remark about the wave calculus: We discuss here only superponible systems. Nerve system shows also counter waves on axons, so called "eating" waves, compare [4], Fig.7. Thus nerve system shows partially more complex behavior.

wave with a *barrier*. But the term wave interference means the interference of *two or more waves*, meeting together at a certain location in a delaying space.

A further source of confusion concerns the use of *Fourier-Transformation* or other integral transformations for wave interference. The phase-space-limitation (0...2π or 0...360°) of *complex number theory* brings confusion into interference systems. Pulse-like systems have a time constant problem: the pulse duration is very shorter the pulse pause, information is lost or destroyed using distances (delays) larger the maximum phase angle (360°) of calculation. By the way: *integral transformations* (Fourier, Laplace, Wavelet...) appear to be interferences between a time function and a set of time functions (coefficients), they can be computed as simplest two-channel interference systems in time domain.

V. TIME FUNCTION AS WAVE

If we suppose (if not otherwise noted) homogeneous fields (for example in case of constant velocity in acoustics) with *delays proportional to distances* between any points or pixels, and we consider a 3-dim. space of nodes we find *circular* moving waves, if we observe subsequent time steps. If we observe *inhomogeneous* fields (nerve nets), we find also waves, but with a *non-circular* size [26].

If we observe *natural time flow*, the *peak* of a circular wave is *outside* and the trough is inside. The *direction* of flow is *expansiv*e. We call this case wave field *projection*.

If we consider *backward flowing time* (Acoustic Camera), we find the wave peak inside and wave trough outside with *implosive* flow direction. We call this case wave field *reconstruction*, see [3].

Example 2. The source point of $f(t)$ has the coordinates $P_0(x_0, y_0, z_0)$. At a pixel $P_1(x_1, y_1, z_1)$ the function may appear delayed by τ_1, the time function is there $f_{P1}(t) = f(t - \tau_1)$. At a different pixel $P_2(x_2, y_2, z_2)$ it appears delayed by $\tau_2$with time function $f_{P2}(t) = f(t - \tau_2)$ and so on.

If time functions flow from different source points over a field, the waves may interfere at some points. If we integrate over each node (point, pixel) in the field long enough, points of wave interference become highlighted, see "*interference integral*" [23], [15].

Basically this technology is used since 1993 for the Acoustic Camera [25], nominated for different awards, beyond a nomination for the *German Future Award 2005*.

Note, that time function waves have not necessary a physical background. We need to know the named proportions: time functions, velocities or delays, locations. This point of view seems to generate an abstract field theory, suitable for nerve nets or technical things, if we can get only time domain measures of any subject.

VI. SELF- AND CROSS INTERFERENCE - TO SEE OR TO HEAR?

Considering an inhomogeneous net, waves meet again at certain locations. If waves by the same time-function origin (wave *i*, *i+1* or *i+2* in Fig.2) meet again, they have very different interference integral properties.

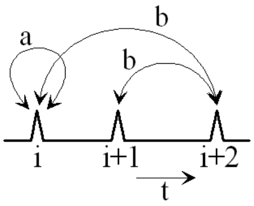

Figure 2. Self-interference (a) and cross-interference between pulses (b)

In case a single wave i meets everywhere in the network her own sister(s) or deviate(s) i, we talk about *self-interference* (*Selbstinterferenz*, Fig.2 case a). Self-interference produces projective maps (images), if the delay space has projective properties (optical lens systems, video cameras, acoustic photo- and cinematography, Sonar, Radar, nerve-projections - Homunculus [27], pictures of thought [10], maps in visual cortex). Thus *self-interference* is the physical basics of *seeing*, of physical image generation.

If we observe a sequence of waves (for example a pulse series $i, i+1, i+2$ ...), waves of different indices (*i* with *i+1*, or *i+1* with *i+2*, case b) interfere also at certain locations. We call this kind *cross-interference* (*Fremdinterferenz*, Fig.2, cases b). While high channel numbers in delay-adjusted systems reproduce the self-interferences (images), low channel numbers underline cross interference locations (frequency maps, aliasing pattern), [12]. Thus *cross-interference* is the physical basics of *hearing*, of noise mapping.

Investigating wave networks we find capabilities for informational tasks, like *temporal to temporal* coding (*bursts*), *spatial to spatial* coding (*projections*), *temporal to spatial* coding (*frequency* maps) or *spatial to temporal* coding (creation of *behavior*), [15].

VII. MASK AND INTERFERENCE INTEGRAL

Up to now, we discussed waves. But linear superimposition of waves makes no image. We need to know more about operators (on nodes) to get images.

Example 3. We suppose waves from different directions coming over a field. Limiting the wave-height between 0 and 1 and *multiplying* all time functions at interesting locations, the resulting wave becomes zero if any of the incoming time functions is zero. It becomes one only at the meeting point of all waves. If we integrate over all points, we get the image.

If we integrate using a non-linear operator (squared addition, multiplication etc.) for a long time over a wave field, points of wave interference become highlighted. We call the result in optics a photograph, in common speaking an interference integral or in acoustics an acoustic image. Also a frequency map is a interference integral, small channel numbers enhance here the cross interference parts.

Supposed, any neuron receives signals (waves) from n different sources, Fig.3.

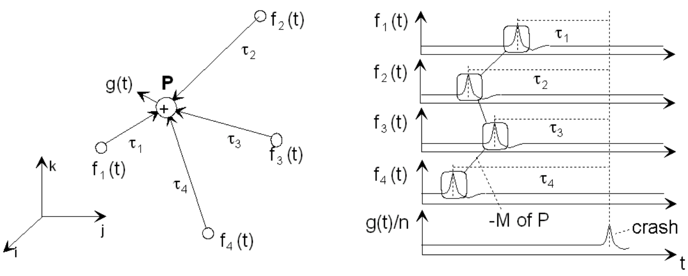

Figure 3. Mask *M* of any spatial arrangement. The time function $g(t)$ at point P adds four source functions $f_k(t)$. Interference in point *P* occurs only, if the input time-function peaks (drawn) are pre-delayed by the mask *M*.

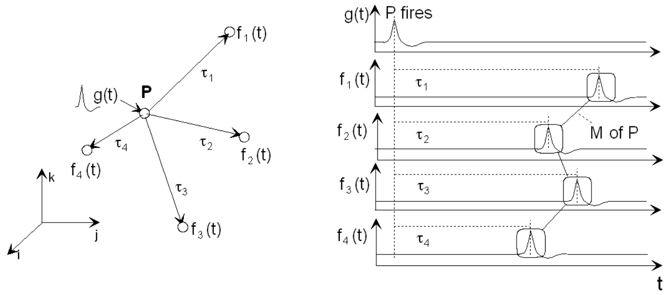

Figure 4. Expansion of a (discrete) wave in 3D-space. A different location of point P corresponds to a different delay mask M. Note the direction of time and delays (mask *M*) of the generator is opposite to the receiver in Fig.3.

Example 4. The (projective) *sum* (effective value) of interferences $g(t)$ of n delaying time functions f_k is at time t and location $P(x_0, y_0, z_0)$

$$g(t) = \frac{1}{n}\sum_{k=1}^{n} f_k(t - \tau_k),\ k = 1...n, \tag{4}$$

with the delay vector (mask)

$$M = (\tau_1, \tau_1, ..., \tau_n). \tag{5}$$

The *interference integral* of n by t_k delayed time functions in a time interval T is a value. By analogy to electrical systems for example the *effective value* is

$$y_{eff} = \sqrt{\lim_{T\to\propto}\frac{1}{T}\int_{-T/2}^{T/2}[\tfrac{1}{n}\sum_{k=1}^{n} f_k(t-\tau_k)]^2 dt}. \tag{6}$$

The equation uses the delay vector M [12]. If pre-delayed by a different $M' \neq M$, the resulting time function $g(t)$ get more and more noise, as more M' differs from M. Maximum interference occurs in P if functions $f_k(t)$ appear exactly pre-delayed with the negative mask vector $-M$ of P (velocity can be slow in neural space).

Opposite case, Fig.4: If a neuron produces an excitement at any location P it burns its delay vector M as address into the resulting time functions (Fig.3). Any spherical shift of P is followed by a different delay vector. That means, the *delay vector represents the location of P*. Looking back into the time functions of Fig.3, we find M looks like a mask. So the *interference reconstruction* can be realized using a so called *mask algorithm* [3]. To get any interference time function $g(t)$ we have to shift the delay mask M of $g(t)$ over the channels $f_k(t)$, adding vertically sample by sample over the holes. Using $f(t+\tau)$ for all pixels this is the main idea for the calculation of acoustic images and films. Doing this, we get a non-mirrored reconstruction of the scene, without of sharpness and over-conditioning problems.

Multiplication and effective value (squared sum) seem to be the limiting methods to calculate interference integrals [23]. Beyond them, nerve nets use polynomial, fuzzy-like behavior [28] between multiplication and addition. Variation between operators corresponds to image qualities, we know from contrast filters: *addition produces weak images*, *multiplication extremely strong* (zero/one) *images*.

A. Projection Equation

Independent, if we consider optics or acoustics or neural nets we find a well known but not named law:

Theorem 5. *Locations of interference (the maximized interference integral) occur there, where partial waves come into coherence again, that means, at locations with equal delay from source point.*

The *point of self interference* has the condition, that *delay sums on all paths are equal.* The sum of delay vector elements of the generating field M_G, the delay vector of the transmitting lines M_T and the delay vector of the detecting field M_D have to be equal. [1] symbolizes a vector of ones [12], that has the size of masks *M*, τ ist the total delay time (scalar) of the circuit,

$$M_G + M_T + M_D = \tau[1] \tag{7}$$

(self interference condition). By analogy we can construct cross interference conditions [15].

B. Projection and Reconstruction

For technical purposes we differ between *projection* (optics, beam forming) and (computational, virtual) *reconstruction.*

Using $f(t+\tau)$ we get the so called *reconstruction* (Acoustic Camera), using $f(t-\tau)$ we get the *projection.* While the time inverse *reconstruction* delivers a one-by-one image, the time-propagating *projection* produces *mirrored* interference integral images [12] with axial sharpness problems know from optics, see Fig.5b). In case of perfect reconstruction the τ in last equation will be zero.

Note, that mathematical projections are the opposite of physical (wave-inferential) projections. The mathematical term is a one-by-one transfer of properties, while the *physical term* has a general *mirroring property.*

C. Image Quality, Conditioning, Space Dimension

Using a d-dimensional space, we need $d + 1$ channels (waves) to mark precise any self interference location, $n = d + 1$.

Using more channels we get *over-conditioned projections* (for example optical lens projections) with an axial near sharpness.

Using a smaller channel number the projection is under-conditioned, it moves. For example we get hyperbolic excitement curves for the case of two channels on a two dimensional surface [10] ($n = d$: under-conditioned).

For natural spaces the space dimension is limited to $d = 3$, that means *acoustic projections* with more then 4 channels become over-conditioned.

To work with high channel numbers (n = 32...256) the acoustic camera uses a time-inverse reconstruction [3] without any over-conditioning effects.

Nerve system can increase the space dimension (and following the channel number) using inhomogeneous spaced nets by velocity-variation (axonal/dendritic diameter changes) and spatial convolution (cortex) [15], [9], [12], [5], [6], [13], [11], [10], [8], [14], [4], [7].

D. Addressable Neurons

Pulse length can be small or large compared to the dendritic and axonal size of a neuron [15], [13], [11]. Any minimum geometrical pulse width λ determines the sharpness maximum of a pulse projection on a core or soma. Pulse width (geometrical wavelength) λ is defined by the pulse peak duration τ and the velocity v

$$\lambda = \tau v \tag{8}$$

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If a neuron must be addressable independent of neighbors, the average distance between neurons is limited to λ.

Example 6. With a pulse peak duration $\tau = 1ms$ and a velocity v = 10 mm/s we get a wave length λ= 10 µm. This is a address grid of 10x10x10 μm^3. We get maximum $1dm^3/10\mu m^3 = 10^{12}$ independent addressable neurons per liter.

Interesting: as slower the velocity (as slower the animal), as smaller is the geometric pulse width and as higher is the address-capacity, however.

Example 7. With a pulse peak duration of 200 s and a velocity of 0,01 m/s, we get a wavelength of 2 Meter, that means the whole body is influenced by that wave (neuro-transmitter, neuro-pharmacy, neuro-peptides). The address volume of the whole body is one: we have no possibility to escape.

E. Refractory Period, Cross-Interference Overflow and Pain

Refractory period is calling the pause between pulse waves. Although in medicine not known, it plays an extremely important role in nerve nets. Like in technical systems, short refractory periods maximize the cross-interference or aliasing pattern. In worst case, a projected image map can not be carried, because the interference integrals of *cross interferences become higher the image integral values*, see the simulation Fig.9 or [29]. We will call this case *cross-interference overflow*.

Example 8. In nerve nets for example the somatotopic maps of body do not project longer into the senso-motor-cortex, because they are overlayed by much more cross interferences. That means, the location sensitivity of the animal disappears, or in opposite direction, the motor-cortex can not longer control any muscle. The individual is in total lethargy. I think, we call this behavior ”pain”.

If we think about mutual (but never found) nociceptors (mechanical receptors for pain), we find them to be redundant. We need only cross-interference overflow. In other words: if some mechanical receptors have together a critical fire rate, all somatotopic projections became overlayed by cross-interference overflow, projections outside the region disappear. *To stop* the process of cross interference overflow, it is only possible *to lengthen the refractory period*. We know, that opiates and other neuro-pharmacy elongate the refractory period: They finish the cross interference overflow - and so the pain.

VIII. TEMPORAL TO TEMPORAL CODING - BURSTS

By analogy to FIR- and IIR-digital filters Fig.5 shows a neuron-like interference circuit, that produces time functions (bursts) b) or that works like a time-function (burst) detector c). All wires might have distributed delays [10]. Using a b-type neuron as generator and a c-type neuron with the negative delay vector $-M$ as detector, such neuron pairs can communicate independent via special bursts on a single line. I called the principle *data-addressing*. If a neural pair has mask-pairs, that are not inverse, the neurons will not communicate.

We can find this effect in case of two neurons with the same spatial structure. If they have identical delay vectors, they avoid uncontrolled feedback between them. So connected, nearest neurons with identical structure can not communicate! We call this *dynamical neighborhood inhibition*. In case, the wavelength is much higher the size of a neuron, or pulses come overlapped in interference, a neuron has the ability to generate floating values, necessary for bias control or for velocity controls via glia-potential [12]. Burst generation, burst detection, data-addressing, neighborhood inhibition and control level generation we will find as *dynamical, elementary functions of neurones* [10], [8].

IX. SPATIAL TO TEMPORAL CODING - THE NEURAL CODE

Assumed, any nerve fiber delay is proportional to length. A code generator in form of Fig.5b produces an output code (time function), that is carried by the intrinsic delays of the structure. So each spherical location of a neuron can receive or transmit a certain time-function, so *delay space codes the*

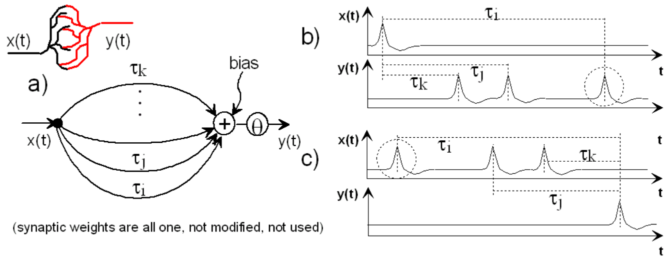

Figure 5. Basic functions of a neuron or a neural group a) Circuit structure, b) Burst generation with low bias, c) Burst detection with high bias

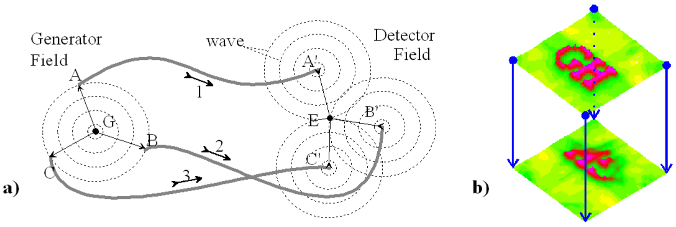

Figure 6. Spatial self interference projection/reconstruction. a) Principle of a wave interference *projection*. b) Reconstruction (top) and projection (bottom) of identical channel data. We find the projection over-conditioned, like an optical lense system, while the reconstruction has no axial restrictions. Simulation: PSI-Tools, GH 08/1996

behavior or delay structure defines the function [15] of an interference circuit.

While any *self interference* of wave *i* with wave *i* (written: [*i, i*], Fig.5) produces the *centered emission only* (projection), all *cross-interferences* of waves *i* with *i-1, i+1, i-2, i+2 ...* produce a map outside the center with emission distances proportional to the difference in pulse refractory distances. A frequency- or code-map appears. In the special case, all delays of a neuron meets waves (burst), this neuron location represents a specific neural code. Neuron will be exited, if the code is detected (receiver). In case of own fire, it generates its own burst (sender). In both cases, it only can detect or transmit its certain burst, see again Fig.5.

X. SPATIAL TO SPATIAL CODING - SELF INTERFERENCE PROJECTION

A certain excitement (point G in Fig.6a) produces a highest interference integral at the interference location (E). This is the place, where all partial waves meet again in self-interference, the delays are equal on all pathways $\tau_1 = \tau_2 = \tau_3$. If we shift point G, we get a shift in point E. Both sides map in a topological relation together. In nerve system we find the term *somatotopy* for topological skin/cortex mappings.

To find locations of interference numerically, the region of interest can be considered as very dense mashed - like a continuous, free wave surface, b). Each co-ordinate in the generator field maps mirroring on a certain co-ordinate in the receiving field.

In [12] some projection-variants were published. Changing the velocity between generator and detector field the projection size *zooms*, the projected image becomes greater or smaller. Changing the delay on any pathway (channel) between generator and detector the projected image *moves* to a different place, *well conditioned projections* with $n = d + 1$ supposed (for example $n = 3$ channels for $d = 2$ surfaces) [12].

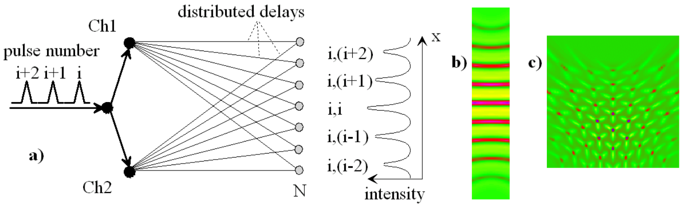

Figure 7. Frequency map as spatial code of a pulse sequence. a) Principle for two channel projection in Huygens-form. b) Interference integral map of the two channel projection. c) Map of a three channel projection. Simulation: PSI-Tools, GH 1996

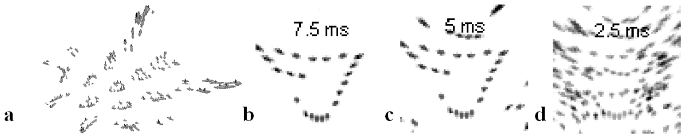

Figure 8. Three channel projections of neurons firing in form of a 'G' with cross interference residua around the self interference figure. Cross interferences appear in the average refractory duration and distance. Subsequent in Fig. a) b), c), d) the refractory pause becomes smaller, cross interferences grow to overflow by the increasing fire rate. Simulation: PSI-Tools, GH 08/1998

XI. TEMPORAL TO SPATIAL CODING

A. Composition and Decomposition

A special sort of projections, called scene composition or decomposition, changes the dimension of an interference projection. For example a 3D-scene (channel number $n = 4$) $P1234$ can correspond to different synchronized 1D-scenes $(n = 2)$ $P12, P23, P34, P41$ or to corresponding 2-dimensional scenes $(n = 3)$ $P123, P234, P341, P412$ and so on. Because of cross-interference noise reasoned by small pulse distances, this is a way to compose projections into high dimensions, see [15], [12], [7]. It allows any interference net (nerve system) a much higher data throughput without reaching the cross-interference limitations of Fig.8.

B. Code- and Frequency-Maps

If a time function wave meets followers with the same origin, we obtain a *cross interference map*, see Fig.7. The geometrical distances of the cross interference maxima appear as function of the geometrical arrangement and as function of the time function parameters (pulse frequency or the pause between pulses - refractory period). The simulation shows, that Huygens double-split experiment can be interpreted very clearly using interference nets.

XII. TOPOMORPHIC OVERLAYED PROJECTIONS

In our imagination it is possible, to overlay images or impressions. Can we find any theoretical evidence for such

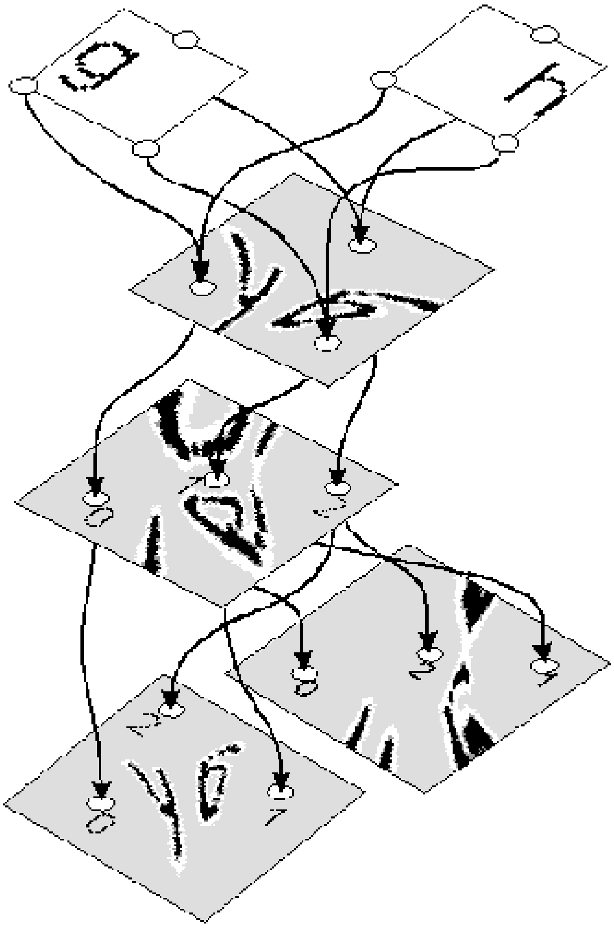

Figure 9. Topomorphic relations between time functions of two sources 'g' and 'h', interfering on different fields. Simulation PSI-Tools, GH 08/1996

behavior? To test this, we overlay two channel data streams, both contain different contents coming from different generator fields 'g' and 'h', Fig.10. Together they project into the same fields, [12] by overlaying (add/append) the channel data streams. Both generator images combine in the receiving fields. If channel source points are moved within the detector fields, the projections become distorted, but they maintain in topomorphic relation. It is not possible to separate 'g' and 'h' again. Note, that all natural projections (with forward time flow) mirror the images!

XIII. Holographic Projections
- In Search of the Engram

Karl Lashley [20] analyzed the location of memorization with trained rats. Independent, which part of the brain he removed, the rats could remember partially a learned behavior (the way through a labyrinth). Remembering, that each pulse is followed practically all the time by a further pulse, self-interference emissions in form of a G are surrounded always by cross-interference figures, Fig.10a.

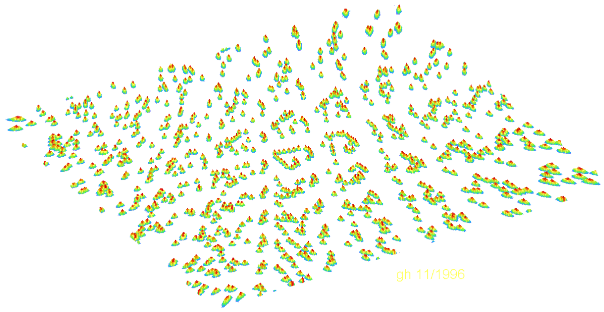

Figure 10. Cross interference figures appear like a hologram around the central self-interference figure 'G'. 3-channel reconstruction with PSI-Tools, GH 11/1996

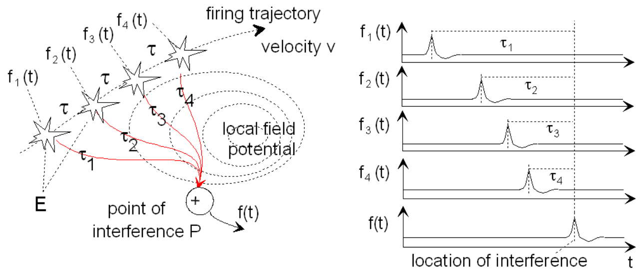

Figure 11. Trajectory examination. If an event (for example a pulse) runs along the trajectory, a specific set of delays will detect it

What a surprise, the *cross interference figures* look similar to the *self interference figure*! The delays between pulses define the cross-interference distance, the distance between the "G" figures. We find, that every memorization in wave interference systems is closely coupled to, what Bohm and Pribram [16], [2], [22] called "holographic content" or "holographic measure". So Lashley had *theoretically* no chance to find clear locations of memorized contents - what a genius concept of nature, and what a tragedy of Lashleys life-long experiments.

But what would happen if we reduce the pause between pulses? The cross interferences comes nearer and nearer, Fig.8b...d [10]. At a certain point the cross interferences overlay the self-interference locations: the projection disappears. If we remember, that the fire rate of sensory neurons increase dramatically in case of injury, we can imagine a possible mechanism of pain.

XIV. Trajectory Examination of Moving Sources

Looking for interference locations, we get a natural way to detect trajectories of moving sources. Supposed we have some in succession firing cells creating a trajectory in form of a moving figure. Neurons on the trajectory (Fig.11) fire consecutively. Interference maximum occurs in P with delay vector $M = (\tau_1, \tau_2, ..., \tau_n)$ for $\tau_n = \tau_{n-1} - \tau$, with $\tau = ds/v$, if ds is a distance and v is the velocity of movement [15], [7]. If a local field potential (glia) controls the velocity or the delays τ_n, different velocities can be observed by variation of field potential.

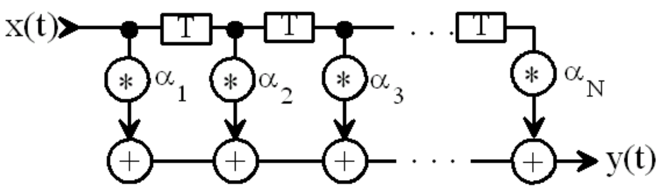

Figure 12. FIR-filter as a specific interference network with unit delays and state abstraction

XV. APPLICATIONS

Worlds first acoustic images and films (1994 - 1996) demonstrated the potential of IN [24]. We used the time-inversive mask algorithm basing on interference reconstruction, with time-inverted waves and negative delays *f(t+T)* [3], [9]. Today, this technology has become a standard approach for acoustic photo- and cinematography. The acoustic camera technology gots worldwide successful and accepted, it is used in most car development centers in the world [25]. The acoustic camera was nominated for different awards, in 2005 we were nominated for the German Future Award. Lots of journalists reported about the technology, see [30].

Thinking about interference networks, we find integral transformations, the global positioning system, digital filters, cellular automaton, convolution coders or control loops. They all can be seen as interference networks. More: Any synchronized system acts as a simplest IN, for example a data latch of a computer or a mixer in a radio receiver. A digital filter (Fig.12) for example can be seen as a discrete, unified interference network variant of Fig.5.

For all IN-systems the *function depends on the arrival time of external events* (inputs).

Example 9. An elevator moves to different floors, if persons on the floors push the buttons at different times. If we record the time functions of buttons, doors and elevator motor, we get a (very poor and discrete) interference network.

This might be surprising, it means that *interference networks bring abstract wave fields into analog and digital circuit theory*, and allow simulations of complexest connected and delayed circuits (nerve nets) although. For further reading, see historic simulations [32] or find more [31].

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