The Application of High Frequency Gravitational Waves to Communication

Presented to the International HFGW Working Group

7 May 2003

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Presentation Outline

- Theoretical Background
- An Assessment of Alternatives for GW Device Concepts: Generators and Sensors
- System Requirements Development: Applying GW to Communication
- One Approach to Possible Early Experimental Verification
- Roadmap for Further Research

Einstein's GR Field Equation

A change in mass – energy distribution will result in a change in space time curvature

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = (8\pi k/c^4) T_{\mu\nu}$$

Eqn. (1)

Space-Time Curvature (Einstein) Tensor

Cosmological Constant

"Coupling" Constant, ~2(10)$^{-43}$ in MKS units

Mass & Energy (Stress-Energy) Tensor

Where:

$G_{\mu\nu} = R_{\mu\nu} - (1/2) g_{\mu\nu} R$

$R_{\mu\nu}$ = **Ricci Tensor**

R = **scalar curvature**

$g_{\mu\nu}$ = **metric tensor**

k = **gravitational constant**

c = **speed of light**

References: Misner, Thorne, & Wheeler (1973), eqn 17.11
Landau & Lifshitz (1975), eqn 95.8

GW Power as a function of Mass-Energy Variation

Radiated Gravitational Wave Power goes as the square Of the change in the acceleration of mass – energy

$$\underbrace{d(E)/dt}_{\text{Radiated Gravitational Wave Power}} = \underbrace{-(k/45c^5)}_{\text{“Coupling” Constant, } \sim 6(10)^{-55} \text{ in MKS units}} \underbrace{[d^3(D_{\alpha\beta})/dt^3]^2}_{\text{Variation in the Mass-Energy Quadrupole Tensor}}$$

Eqn. (2)

Where:

$d(E)/dt$ = **GW power**

E = **GW energy**

k = gravitational constant

C = **speed of light**

$D_{\alpha\beta}$ = **mass – energy quadrupole tensor**

Reference: Landau & Lifshitz (1975), eqn 110.16

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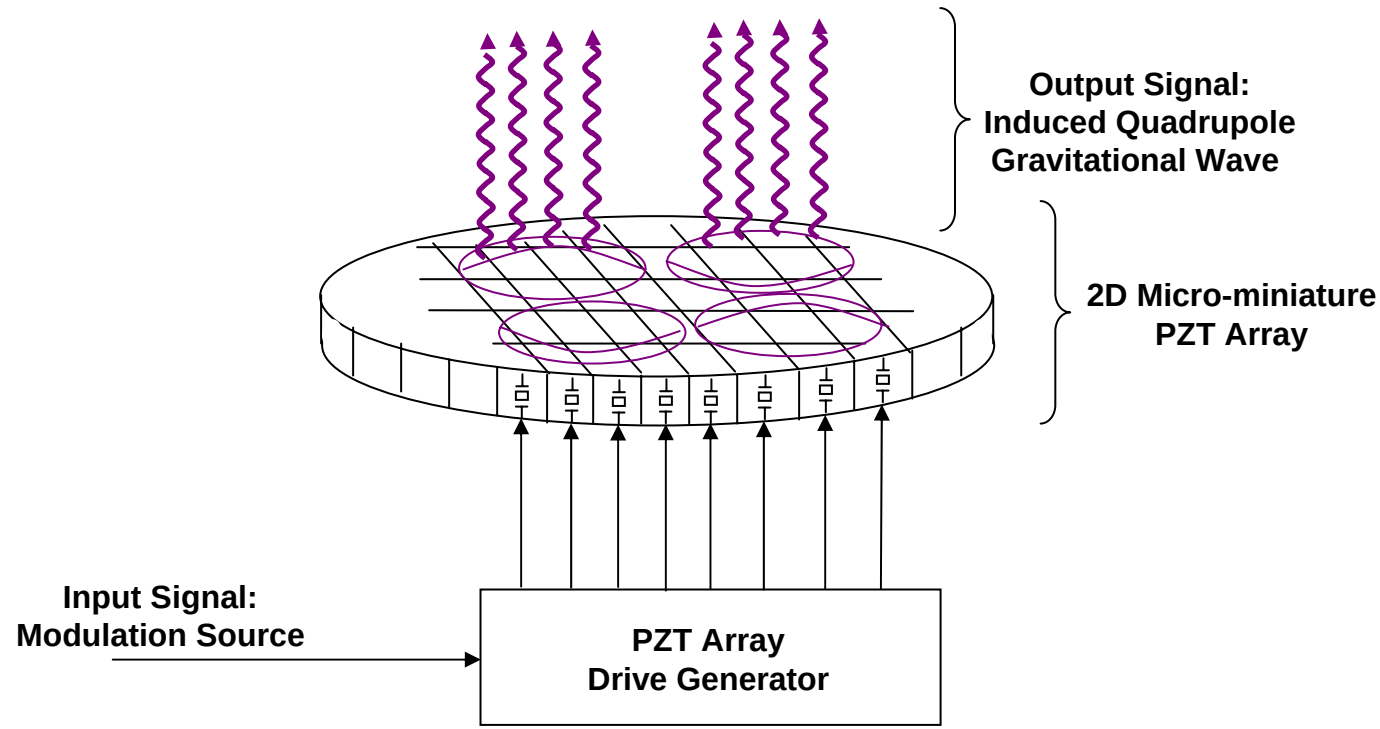
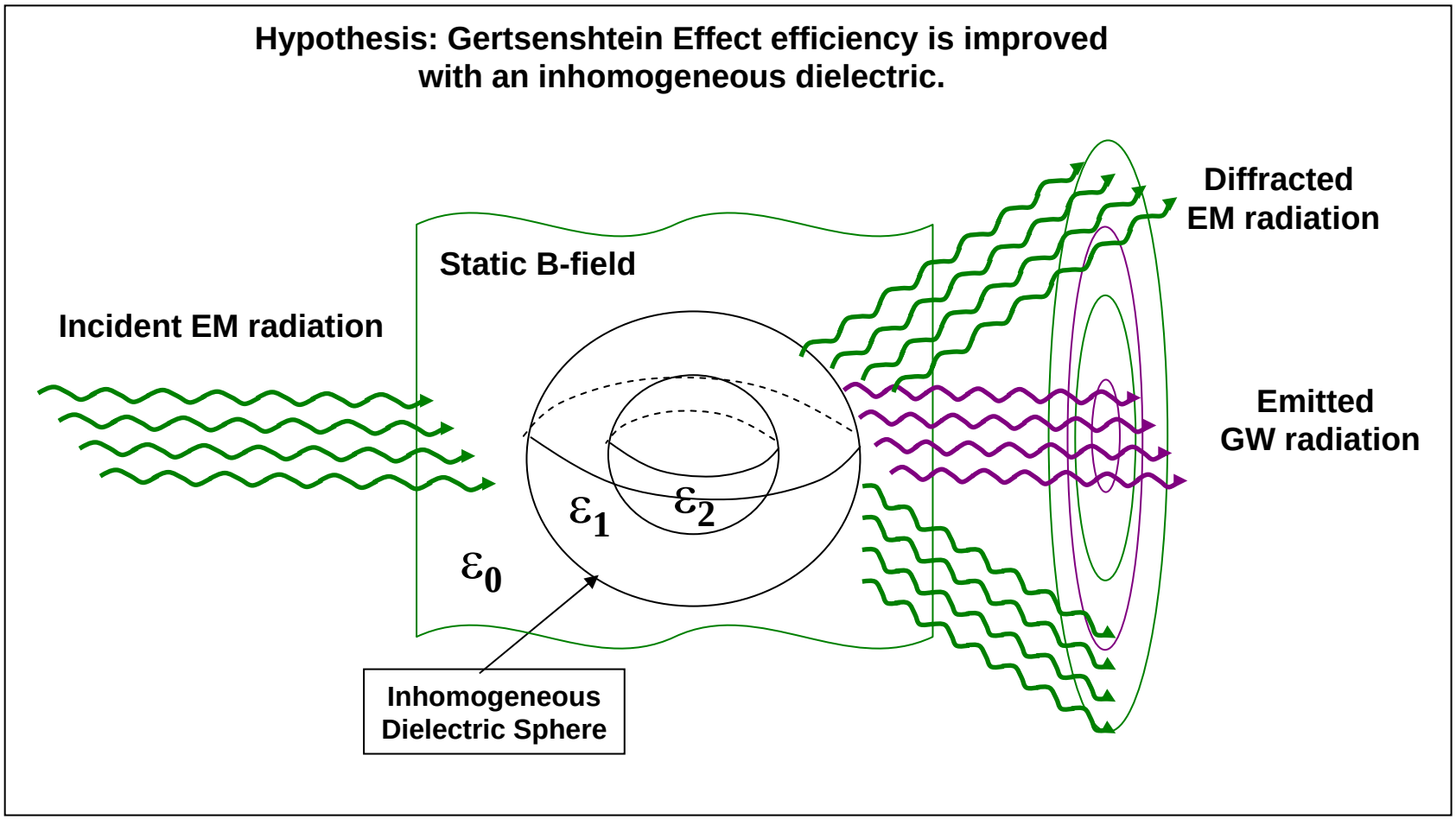
Generator Concept – Array of Sync'ed Mini PZTs (Romero & Dehnen)

Hypothesis: A PZT array can be used to create mechanical displacements in a quadrupole pattern to create gravitational waves.

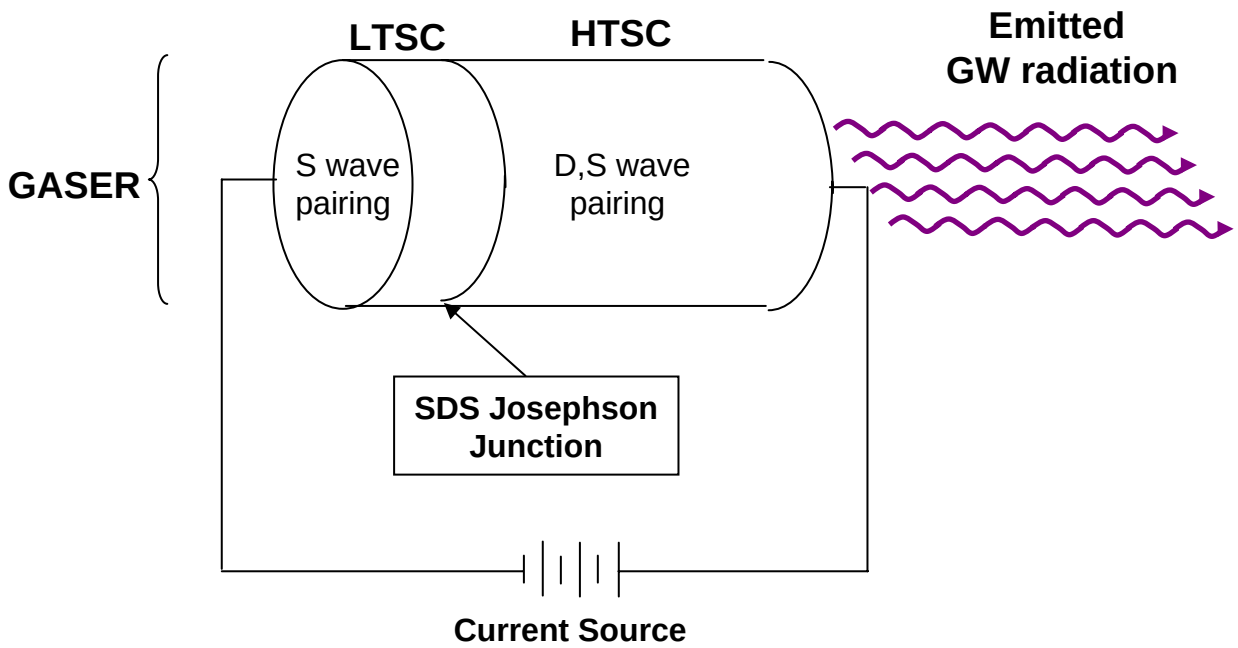


Generator Concept – Dielectric Sphere (Portilla & Lapiedra)



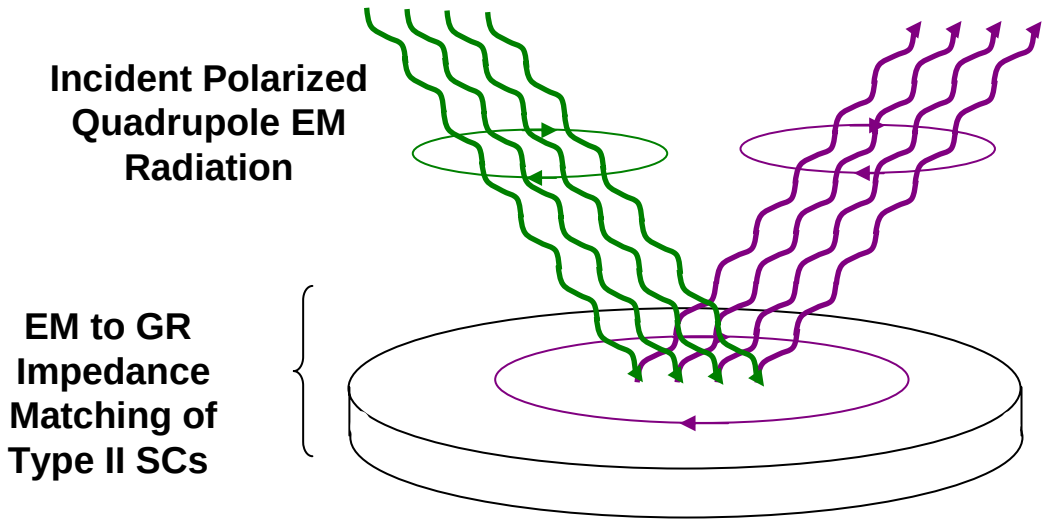
Generator Concept – HTSC GASER (Fontana)

Hypothesis: Stimulated emission of gravitons is achieved by coherent gravitational quadrupolar quantum transitions.



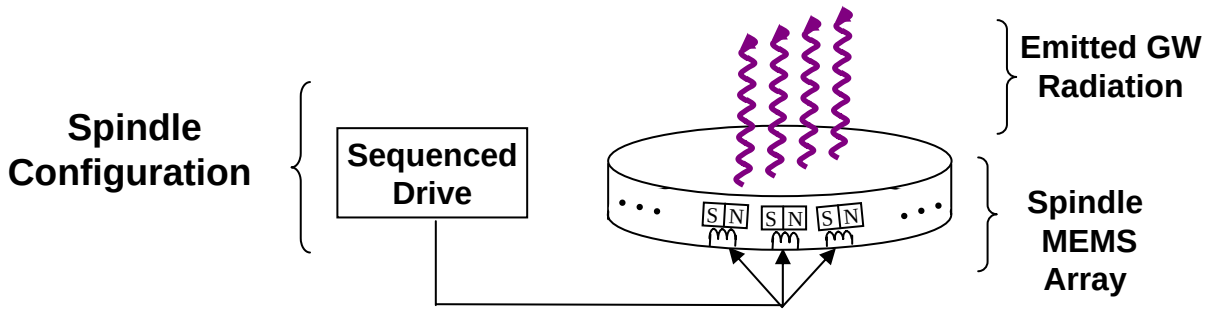
Generator Concept – HTSC with Polarized EM for GR frame dragging (Chaio)

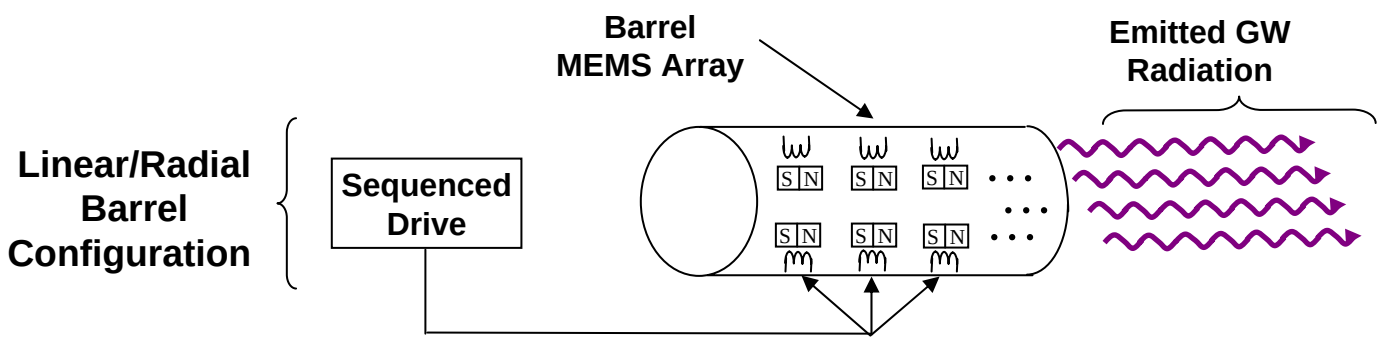
Hypothesis: Type II Superconductors convert conditioned EM to GR frame dragging by virtue of their natural impedance matching properties.



Generator Concept – Nanotechnology Electro-Mechanical (Baker)

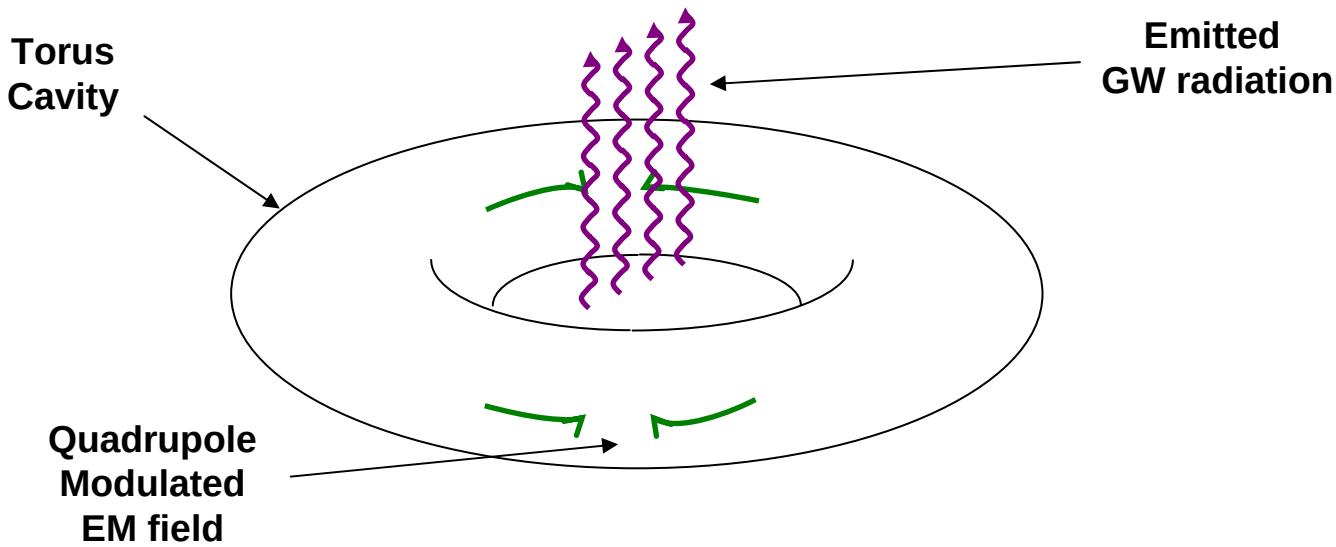
Hypothesis: Nanotechnology arrays of actuated charges or magnets can be used as a source of gravitational wave emission.





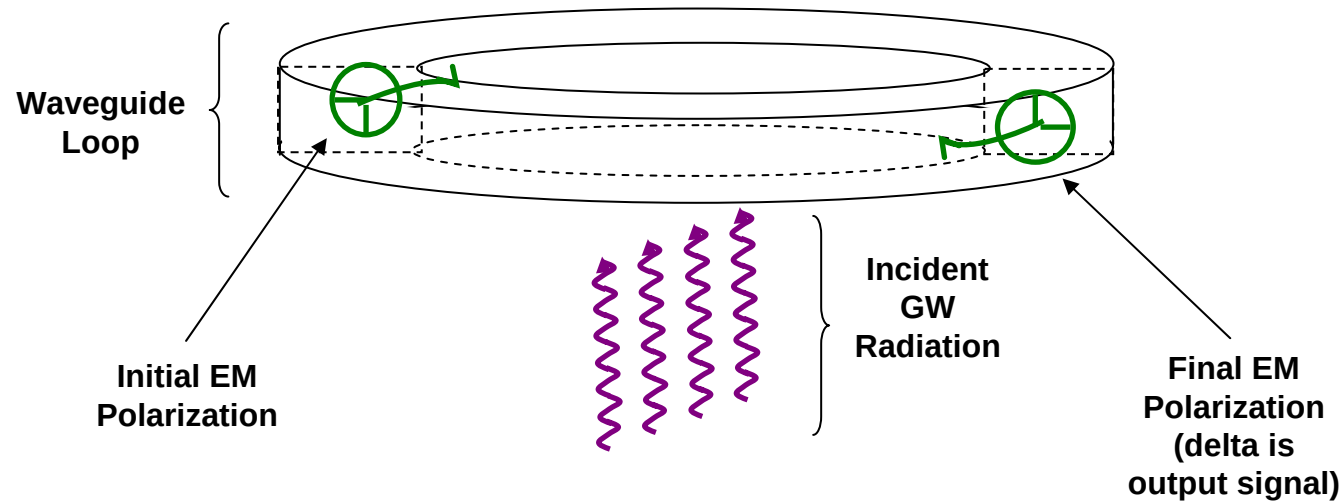
Generator Concept – Toroid with EM (Grishchuk & Sazhin)

Hypothesis: An EM resonator in the form of a torus in which an alternating EM field is excited can be used as a source of gravitational wave emission.



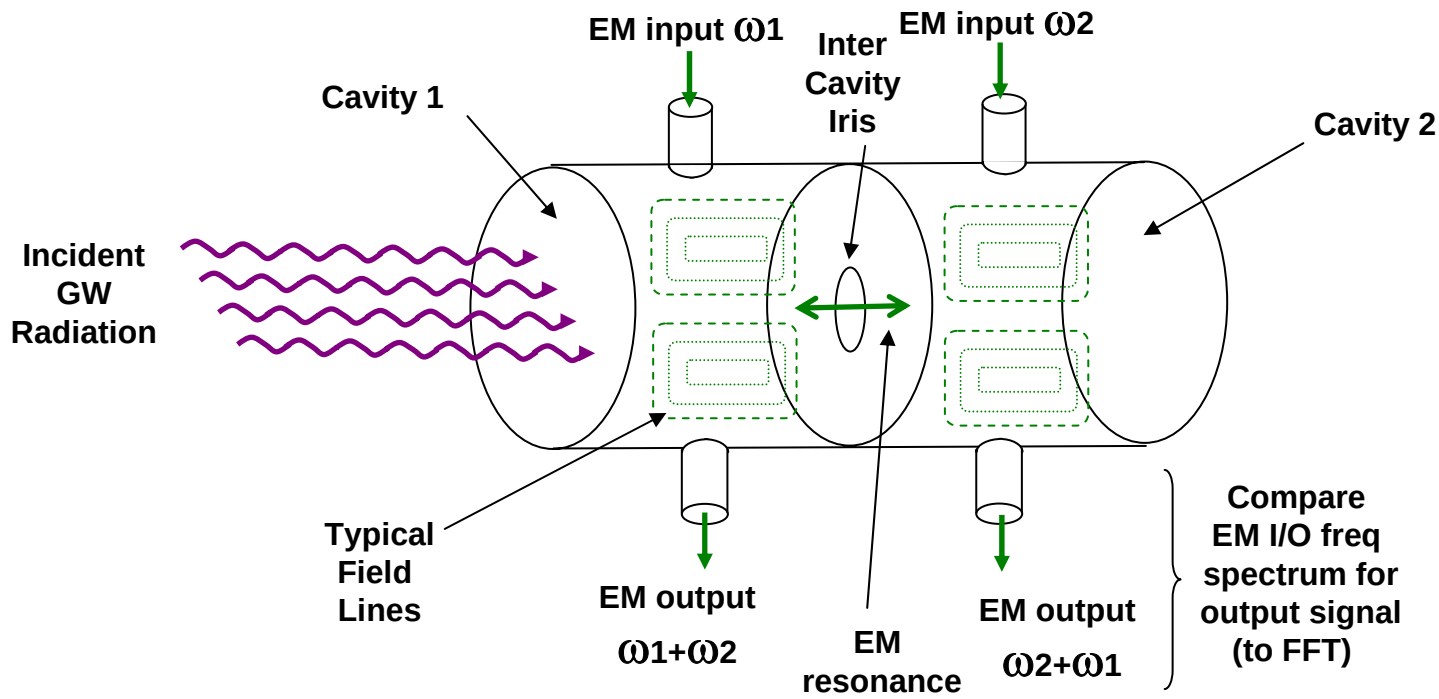
Sensor Concept – Circular Waveguide (Ingley & Cruise)

Hypothesis: A waveguide ring containing a polarized EM wave will experience a polarization change when gravitational waves of the same wavelength pass through the waveguide ring.



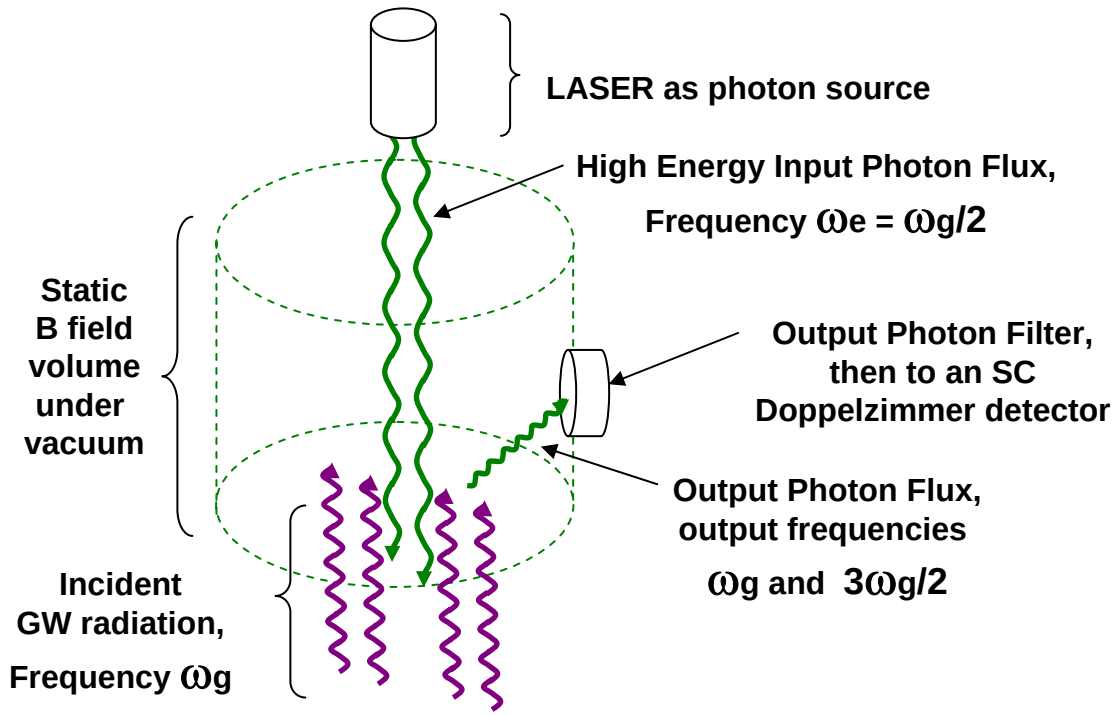
Sensor Concept – Coupled EM Cavities (Bernard, Gemme, et.al.)

Hypothesis: A gravitational wave incident on a pair of tuned resonant cavities will cause those cavities to alter their resonant behavior.



Sensor Concept – Static Magnetic Field with EM Sense Beam (F-Y Li, et. al.)

Hypothesis: A gravitational wave in a static B field will have a resonant response to a half frequency photon beam, creating new photon frequency outputs.



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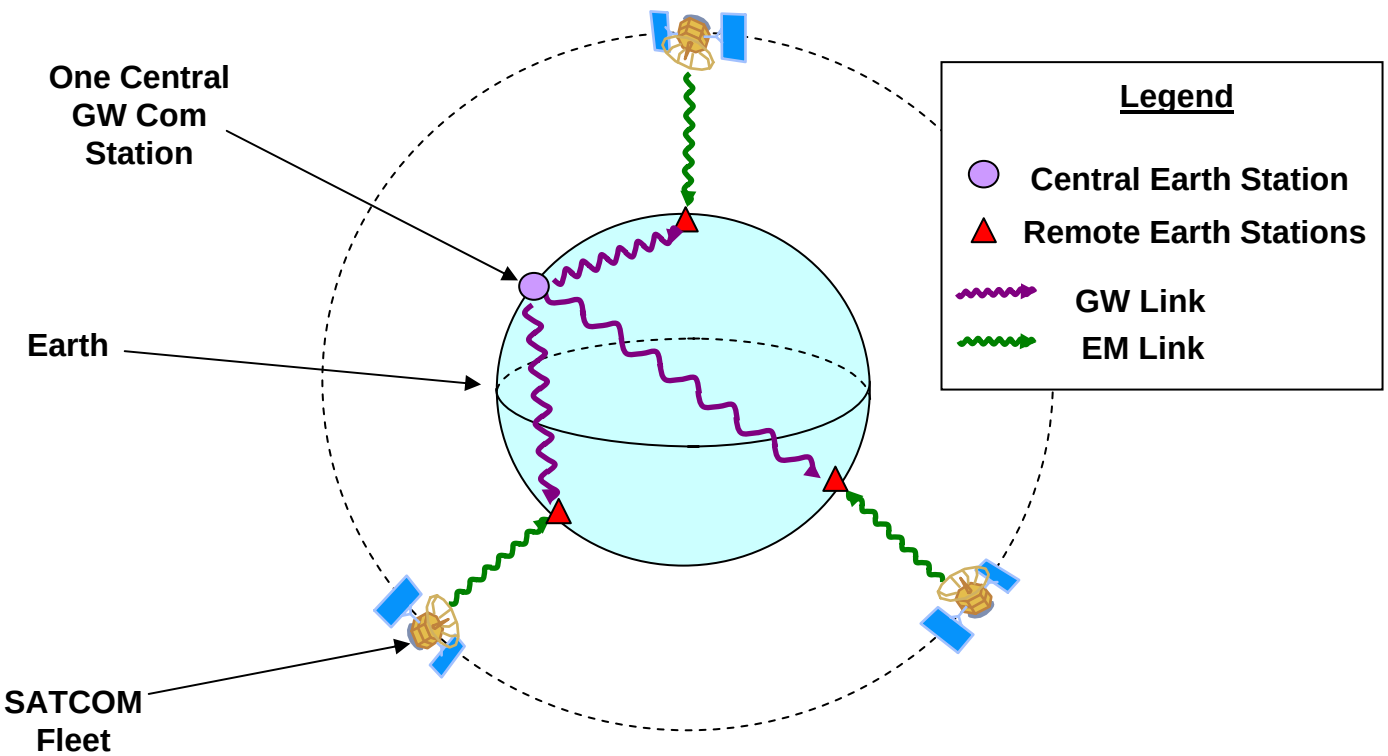
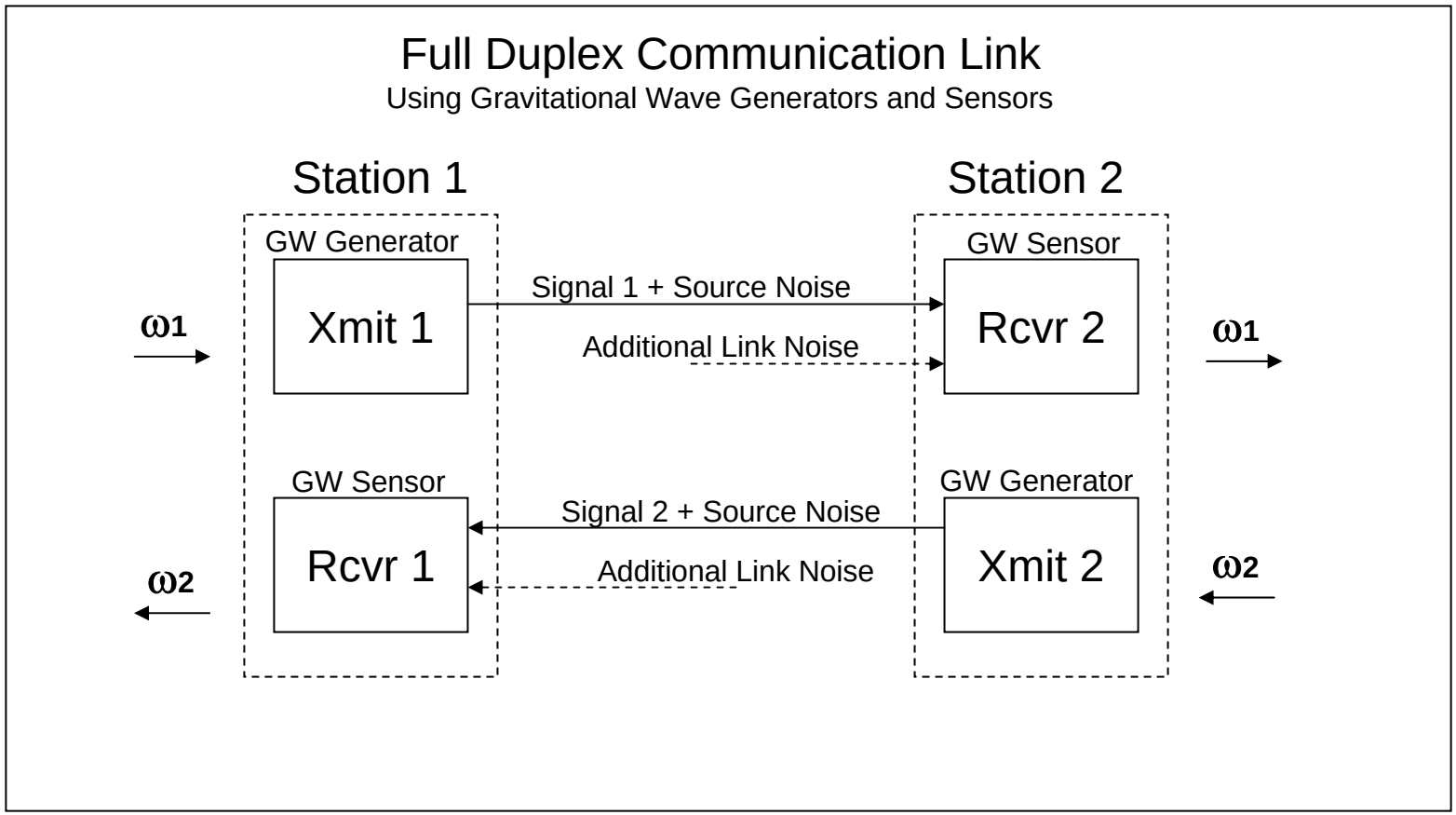
GW propagation verses SATCOM (Satellite Communication)

Using gravitational waves, one ground station could theoretically replace an entire satellite constellation.

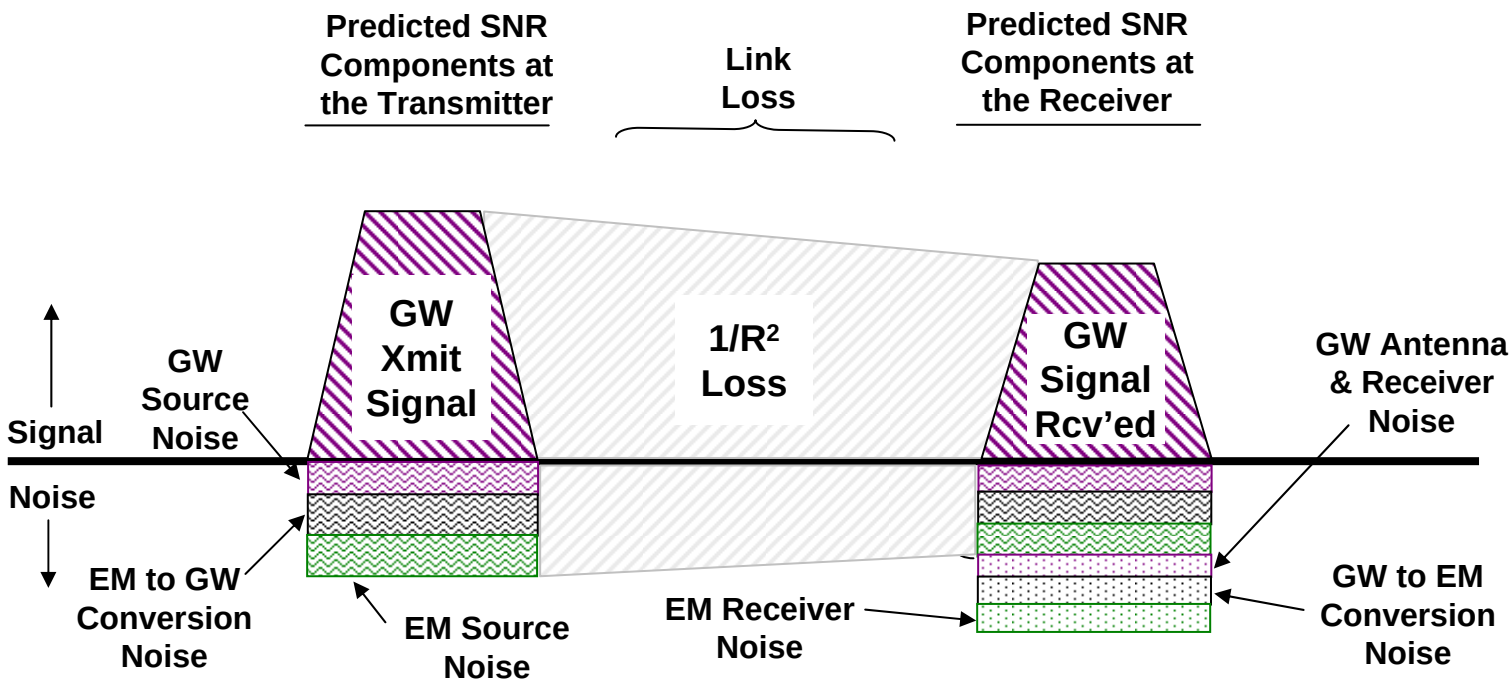


GW Communication System Block Diagram



Conceptual SNR fill factors

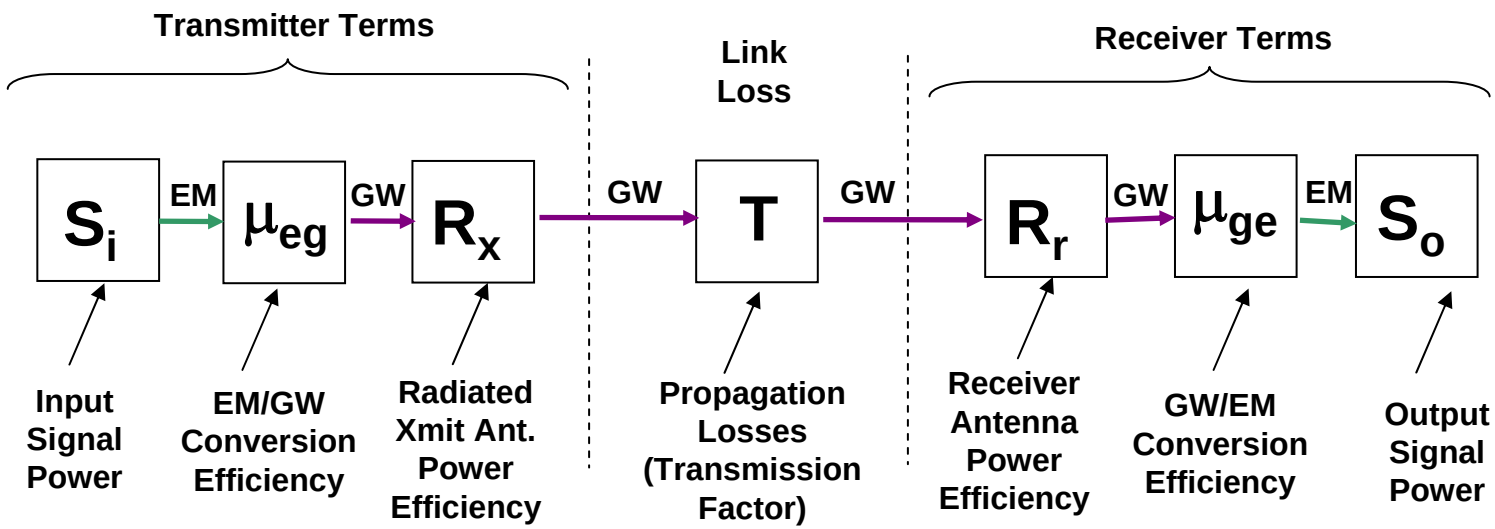
Signal to noise ratios (SNR's) at the transmitter and at the receiver must be calculated to support a communications link design.



Block Diagram of Typical Link Budget

An end-to-end power link budget from the transmitter to the receiver must be also calculated to support a communications link design.

$$S_o = \int_{\lambda 1}^{\lambda 2} R_r \, \mu_{ge}\{T(R_x \, \mu_{eg}[S_i])\}d\lambda \qquad \text{Eqn. (3)}$$



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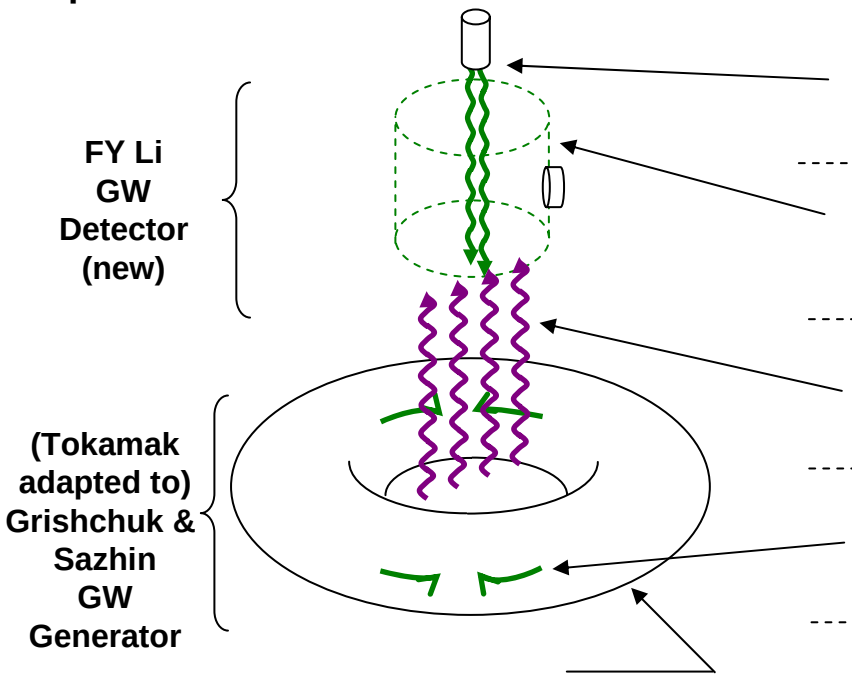
Fusion Tokamak Modified for GW Research, & ROM Parameter Estimate

It may be possible to adapt a fusion tokamak to perform GW research:



Design Parameter	Parameter Description	Value & Units*
P_s	Sense Beam Power	10^6 W
B_z	Static Sense B Field Strength	30 T
A	GW Amplitude	10^{-33}
W_{gen}	Generator EM field Energy Density	10^9 J/m^3

*Based on FY Li (2000), Table I

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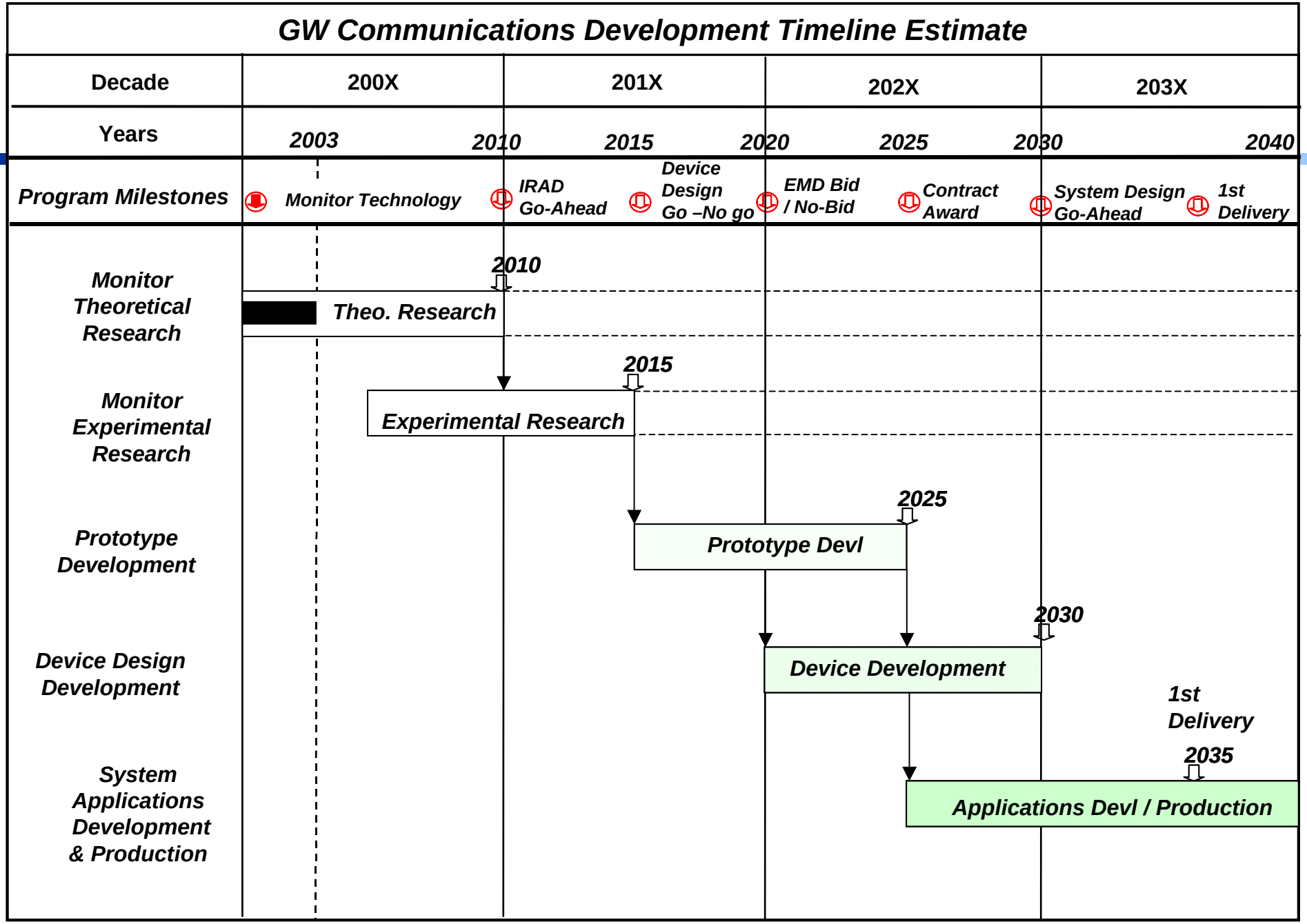
Typical Technology Development Timelines

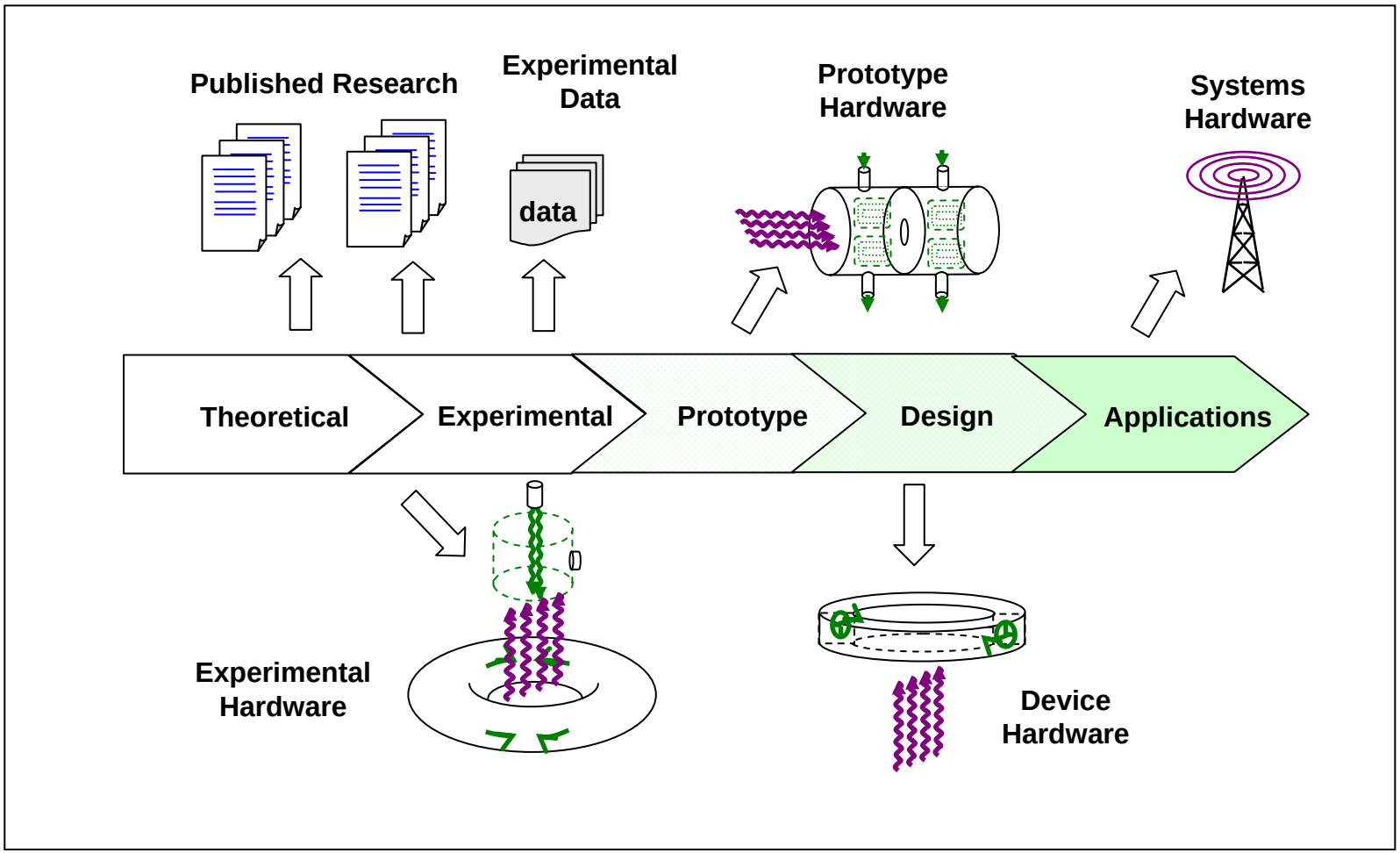
Technology	Kickoff Invention	Inv Date	Commerciallization Marker	Com Date	Period (yrs)
Electricity	Edison's Light Bulb	1879	Electrification of Urban America	1920	41
Computers	Hollerith's Punch Card Patent	1889	IBM PC XT Introduced	1983	94
Radio	Marconi's Wireless	1895	Worldwide Nautical Service Starts	1929	34
Aircraft	Wright Brother's First Flight	1903	DC3 Rollout	1935	32
Chemical Rockets	Goddard First Liquid Fuel Rocket	1926	Intelsat Global Coverage Starts	1969	43
Nuclear Power	Atomic Bomb	1945	ITER Commercial Fusion Plant	2045	100
Networks	ARPAnet goes on line	1969	Internet goes public	1992	23

30 to 40 year development timelines are typical for new (first generation) technologies.

- Longer timelines may actually represent multiple generations.
- For gravitational wave technology, when did (does) the clock start?


GW Communications Development Timeline Estimate
Decade
200X
201X
202X
203X
Years
2003
2010
2015
2020
2025
2030
2040
Program Milestones
Monitor Technology
IRAD Go-Ahead
Device Design Go –No go
EMD Bid / No-Bid
Contract Award
System Design Go-Ahead
1st Delivery
Monitor Theoretical Research
2010
Theo. Research
Monitor Experimental Research
2015
Experimental Research
Prototype Development
2025
Prototype Devl
Device Design Development
2030
Device Development
1st Delivery
2035
System Applications Development & Production
Applications Devl / Production

Research Products by Phase



Backup Slides

2003 International HFGW

G.V. Stephenson

GW Valve Concept – Spinning HTSC in an Alternating Magnetic field (Podkletnov)

Hypothesis: Rotating a type II superconductor through an alternating magnetic field causes shielding via gravitational wave annihilation due to gravito-electric to gravito-magnetic frame transformation.