fizika.pmf.ni.ac.rs

svetnauke.org

Fizika mobilnog telefona

MILAN MILOŠEVIĆ
Departman za fiziku
Prirodno-matematički fakultet u Nišu

Prezentacija radova „Mobilni telefon u fizičkom eksperimentu"
20. april 2019, PMF, Niš

Zadatak za razmišljanje ☺

- Koristeći materijal dostupan u kući/amfiteatru izmeriti obim Zemlje…

Istorija

- 1873. – J. Maksvel – teorija elektromagnetizma
- 1876. – A. Bel – prvi telefon (takođe prvi „fotofon" – preteča bežičnih telefona)
- 1888. – H. Herc – prvi elektromagnetni talasi i laboratoriji
- 1894. – O. Lodž – prva poruka preko radio talasa (Oksford)
- 1899. – G. Markoni – prva poruka preko Engleskog kanala (1901. preko Atlantika)
- 1906. – R. Fesenden – prva glasovna poruka
- 1920-te - Hitne službe počinju da koriste bežične telefone

Istorija

- 1940-te – mobilni telefoni postaju popularni u hitnim i taksi službama
- 1946. – AT&T presttavio svoj Mobile Telephone System (MTS) za slanje radio signala između vozila
- 1960-te – Belove laboratorije razvijaju mobilne telefone za vozove
- 1973. M. Kuper (Motorola) predstavio prvi prenosni mobilni telefon (patent 1975.)

Fizika mobilnog telefona

- Maksvelove jednačine

$$\oiint_{\partial\Omega} \vec{E} \cdot d\vec{S} = \frac{1}{\varepsilon_0} \iiint_{\Omega} \rho dV \qquad \nabla \vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\oiint_{\partial\Omega} \vec{B} \cdot d\vec{S} = 0 \qquad \nabla \vec{B} = 0$$

$$\oint_{\partial\Sigma} \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \iint_{\Sigma} \vec{B} d\vec{S} \qquad \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\oint_{\partial\Sigma} \vec{B} \cdot d\vec{l} = \mu_0 \iint_{\Sigma} \vec{j} \cdot d\vec{S} + \mu_0 \varepsilon_0 \frac{d}{dt} \iint_{\Sigma} \vec{E} \cdot d\vec{S} \qquad \nabla \times \vec{B} = \mu_0 \left(\vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{dt} \right)$$

- Šredingerova jednačina

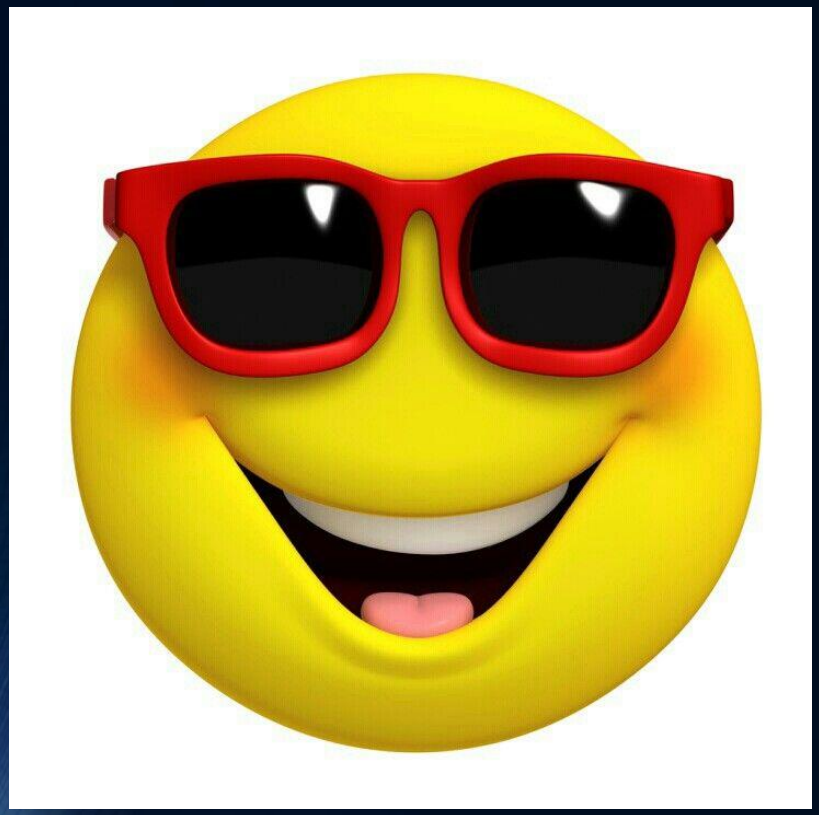
$$i\hbar \frac{\partial}{\partial t} \psi(\vec{r}, t) = \left[\frac{-\hbar^2}{2\mu} \nabla^2 + V(\vec{r}, t \right] \psi(\vec{r}, t)$$

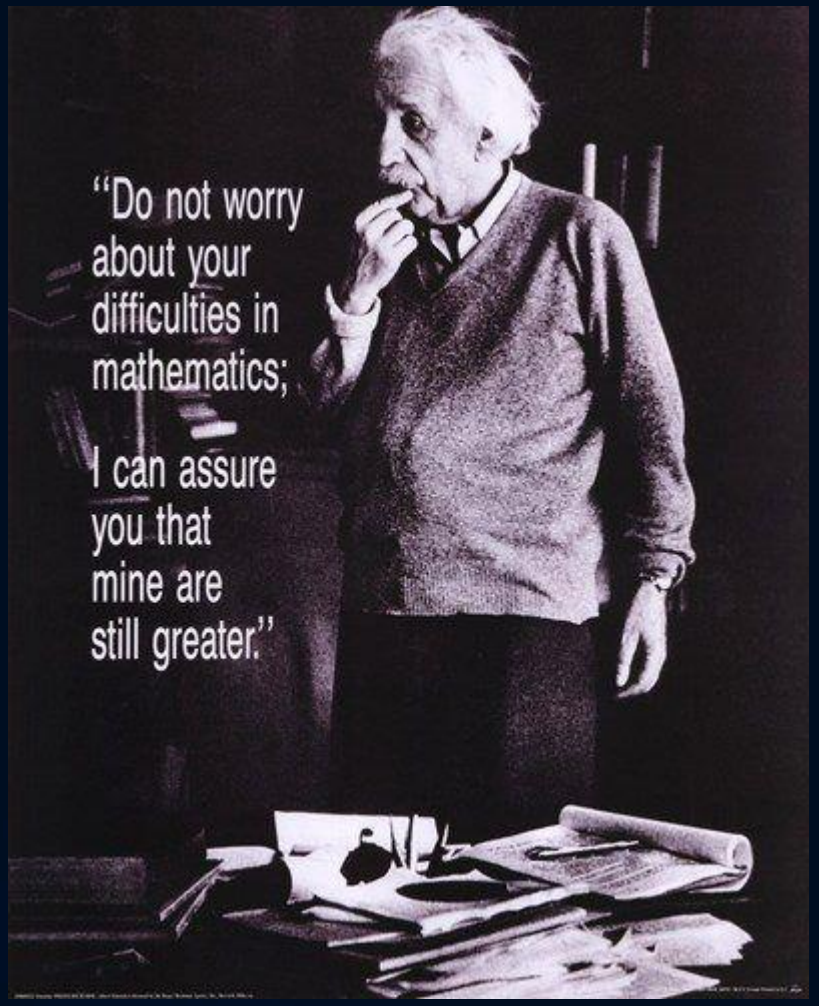
- Opšta teorija relativnosti

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Lagranžijan Standardnog modela

$$\mathcal{L}_{SM} = -\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - igc_w(\partial_\nu Z^0_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - Z^0_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)) - igs_w(\partial_\nu A_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)) - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2 (Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + g^2 s_w^2 (A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w (A_\mu Z^0_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu) - \tfrac{1}{2}\partial_\mu H \partial_\mu H - 2M^2 \alpha_h H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \beta_h \left(\tfrac{2M^2}{g^2} + \tfrac{2M}{g}H + \tfrac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-) \right) + \tfrac{2M^4}{g^2}\alpha_h - g\alpha_h M \left(H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-\right) - \tfrac{1}{8}g^2 \alpha_h \left(H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2 H^2\right) - gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig\left(W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)\right) + \tfrac{1}{2}g\left(W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) + W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)\right) + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) + M\left(\tfrac{1}{c_w}Z^0_\mu\partial_\mu\phi^0 + W^+_\mu\partial_\mu\phi^- + W^-_\mu\partial_\mu\phi^+\right) - ig\tfrac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \tfrac{1}{4}g^2 W^+_\mu W^-_\mu \left(H^2 + (\phi^0)^2 + 2\phi^+\phi^-\right) - \tfrac{1}{8}g^2\tfrac{1}{c_w^2}Z^0_\mu Z^0_\mu \left(H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2\phi^+\phi^-\right) - \tfrac{1}{2}g^2\tfrac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) - \tfrac{1}{2}ig^2\tfrac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \tfrac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) + \tfrac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\tfrac{s_w}{c_w}(2c_w^2 - 1)Z^0_\mu A_\mu\phi^+\phi^- - g^2 s_w^2 A_\mu A_\mu\phi^+\phi^- + \tfrac{1}{2}ig_s\lambda^a_{ij}(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda(\gamma\partial + m^\lambda_\nu)\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m^\lambda_u)u^\lambda_j - \bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_w A_\mu\left(-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)\right) + \tfrac{ig}{4c_w}Z^0_\mu\{(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{d}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 - 1 - \gamma^5)d^\lambda_j) + (\bar{u}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 + \gamma^5)u^\lambda_j)\} + \tfrac{ig}{2\sqrt{2}}W^+_\mu\left((\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)U^{lep}{}_{\lambda\kappa}e^\kappa) + (\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)\right) + \tfrac{ig}{2\sqrt{2}}W^-_\mu\left((\bar{e}^\kappa U^{lep\dagger}{}_{\kappa\lambda}\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\kappa\lambda}\gamma^\mu(1+\gamma^5)u^\lambda_j)\right) + \tfrac{ig}{2M\sqrt{2}}\phi^+\left(-m^\kappa_e(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1-\gamma^5)e^\kappa) + m^\lambda_\nu(\bar{\nu}^\lambda U^{lep}{}_{\lambda\kappa}(1+\gamma^5)e^\kappa)\right) + \tfrac{ig}{2M\sqrt{2}}\phi^-\left(m^\lambda_e(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1+\gamma^5)\nu^\kappa) - m^\kappa_\nu(\bar{e}^\lambda U^{lep\dagger}{}_{\lambda\kappa}(1-\gamma^5)\nu^\kappa)\right) - \tfrac{g}{2}\tfrac{m^\lambda_\nu}{M}H(\bar{\nu}^\lambda\nu^\lambda) - \tfrac{g}{2}\tfrac{m^\lambda_e}{M}H(\bar{e}^\lambda e^\lambda) + \tfrac{ig}{2}\tfrac{m^\lambda_\nu}{M}\phi^0(\bar{\nu}^\lambda\gamma^5\nu^\lambda) - \tfrac{ig}{2}\tfrac{m^\lambda_e}{M}\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda) - \tfrac{1}{4}\,\bar{\nu}_\lambda\, M^R_{\lambda\kappa}\,(1-\gamma_5)\hat{\nu}_\kappa - \tfrac{1}{4}\,\bar{\nu}_\lambda\, M^R_{\lambda\kappa}\,(1-\gamma_5)\hat{\nu}_\kappa + \tfrac{ig}{2M\sqrt{2}}\phi^+\left(-m^\kappa_d(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + m^\lambda_u(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j)\right) + \tfrac{ig}{2M\sqrt{2}}\phi^-\left(m^\lambda_d(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1-\gamma^5)u^\kappa_j)\right) - \tfrac{g}{2}\tfrac{m^\lambda_u}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2}\tfrac{m^\lambda_d}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m^\lambda_u}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \tfrac{ig}{2}\tfrac{m^\lambda_d}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu\bar{G}^a G^b g^c_\mu + \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \tfrac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar{X}^0 X^- - \partial_\mu\bar{X}^+ X^0) + igs_w W^+_\mu(\partial_\mu\bar{Y}X^- - \partial_\mu\bar{X}^+ Y) + igc_w W^-_\mu(\partial_\mu\bar{X}^- X^0 - \partial_\mu\bar{X}^0 X^+) + igs_w W^-_\mu(\partial_\mu\bar{X}^- Y - \partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+ X^+ - \partial_\mu\bar{X}^- X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+ X^+ - \partial_\mu\bar{X}^- X^-) - \tfrac{1}{2}gM\left(\bar{X}^+X^+H + \bar{X}^-X^-H + \tfrac{1}{c_w^2}\bar{X}^0X^0H\right) + \tfrac{1-2c_w^2}{2c_w}igM\left(\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-\right) + \tfrac{1}{2c_w}igM\left(\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-\right) + igMs_w\left(\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-\right) + \tfrac{1}{2}igM\left(\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0\right).$$




"Do not worry
about your
difficulties in
mathematics;
I can assure
you that
mine are
still greater."

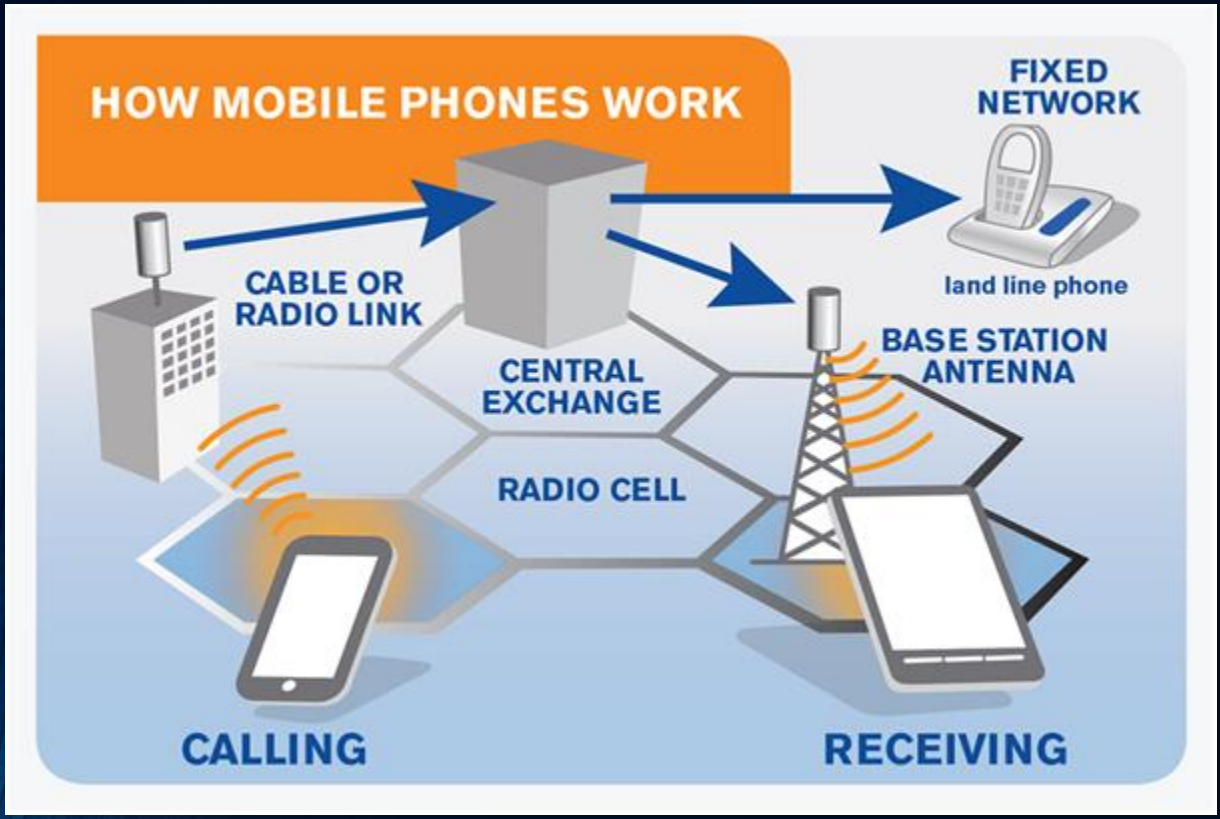
Prvi mobilni telefoni

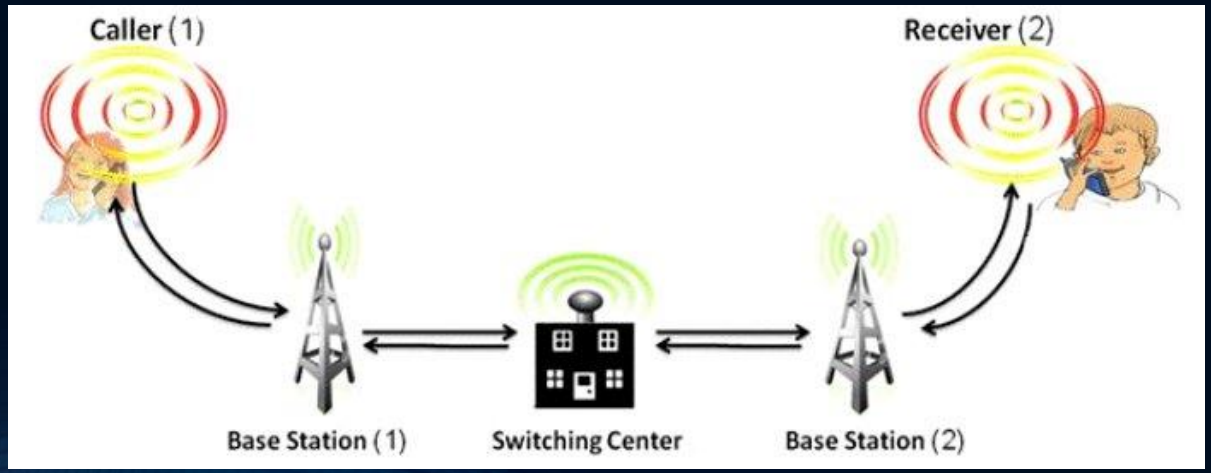
- Do 1973 (levo); DynaTAC 8000X (desno)
- Masa 790 grama, 25 cm (bez antene), 30 min razgovora i 10 sati punjenja baterije

Mobilna mreža

- Analogni sistem mobilnih telefona (1978) u Čikagu
- 1982. – Evropske kompanije – Globalni Sistem Mobilnih komunikacija (GSM)
- 1984 – Motorola DynaTAC prvi komercijalni telefon
- 1995 – GSM prihvaćen u SAD
- 2001 – GSM dostiže udeo od 70% globalne primene
- 2000+ - treća generacija (3G) telefona
- 2007 – Apple revolucija i ekrani na dodir

Prvi (intergalaktički) telefon

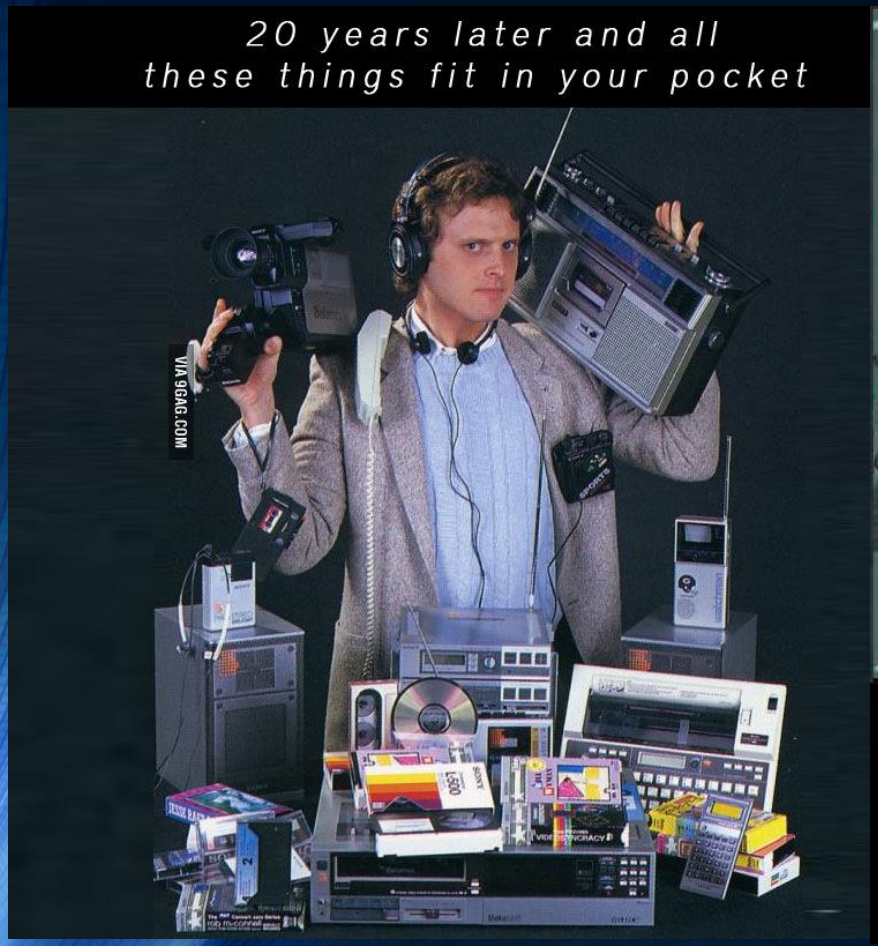

HOW MOBILE PHONES WORK
FIXED NETWORK
land line phone
CABLE OR RADIO LINK
CENTRAL EXCHANGE
BASE STATION ANTENNA
RADIO CELL
CALLING
RECEIVING

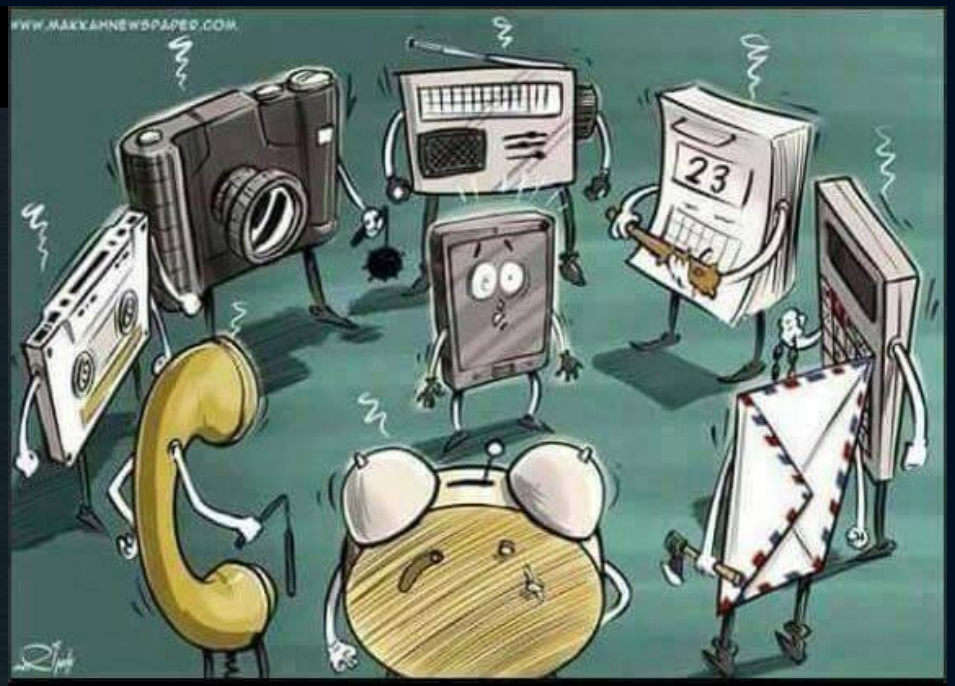

Caller (1)
Receiver (2)
Base Station (1)
Switching Center
Base Station (2)

Evolucija telefona

Evolucija mobilnih telefona

Mobilni telefoni danas





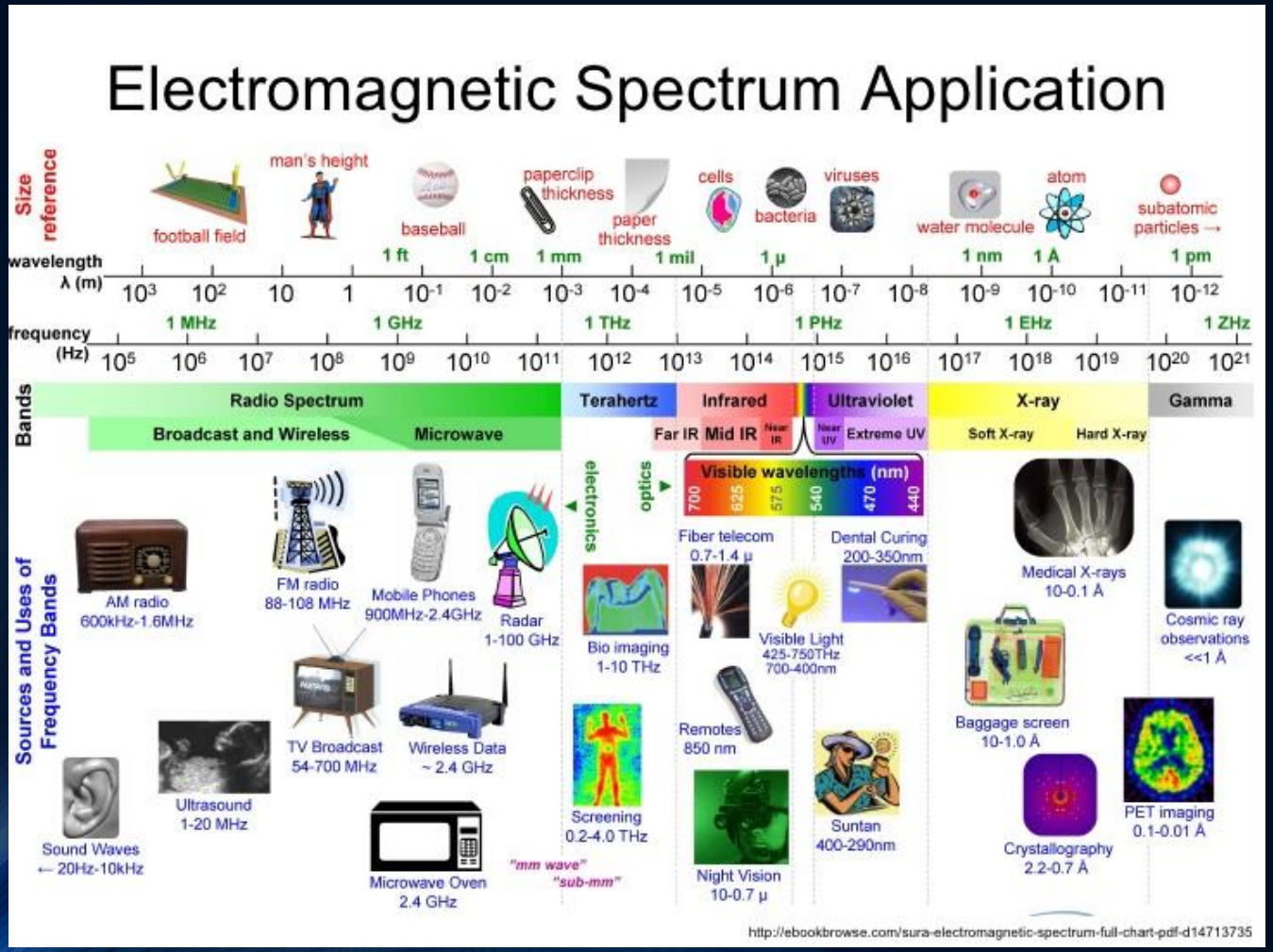
Znači ti si taj koji nam je uzeo posao ...

Ipak... ima i onih...

F I Z I K A

u i na mobilnom telefonu

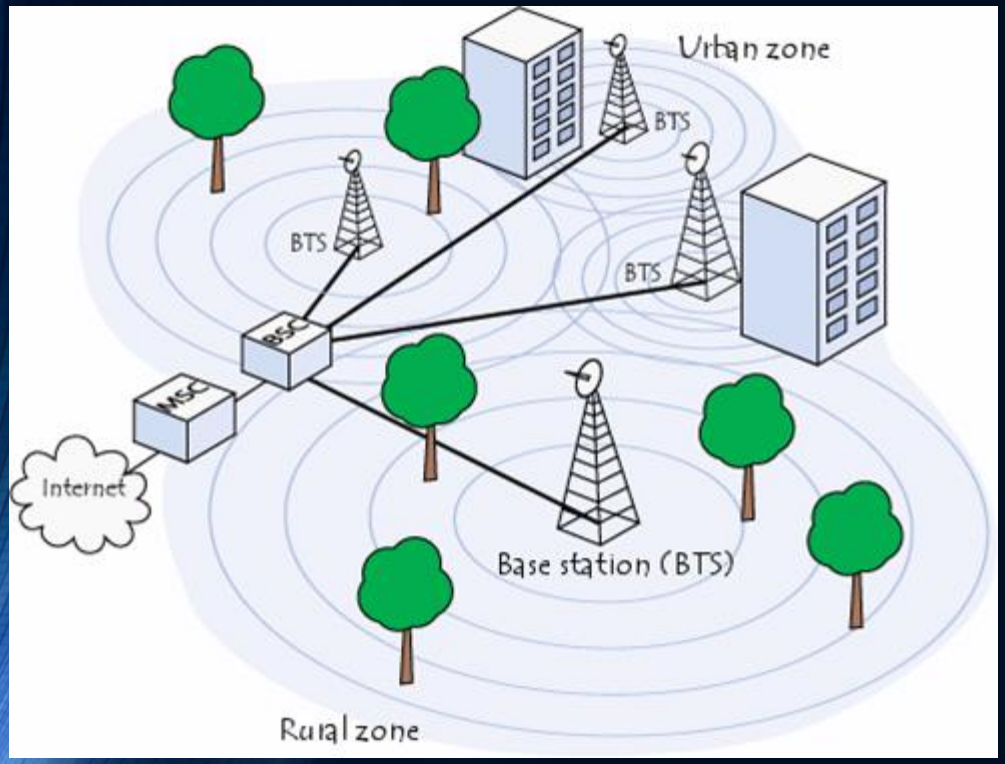
Prostiranje talasa



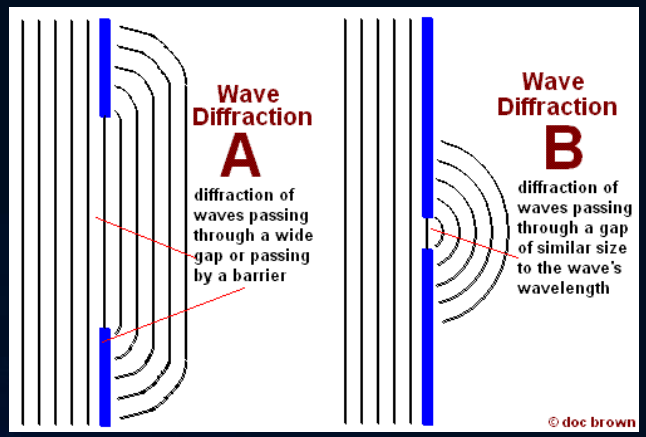
Antena

- Toki-voki - jak signal; mobilni – slab signal
- Bazne stanice – 10-50 W, telefoni 2W
  - Snaga opada sa kvadratom rastojanja; 100 puta jači emiter – samo 10 puta veće rastojanje
- Radio i TV predajnici nekoliko desetina-stotina kW

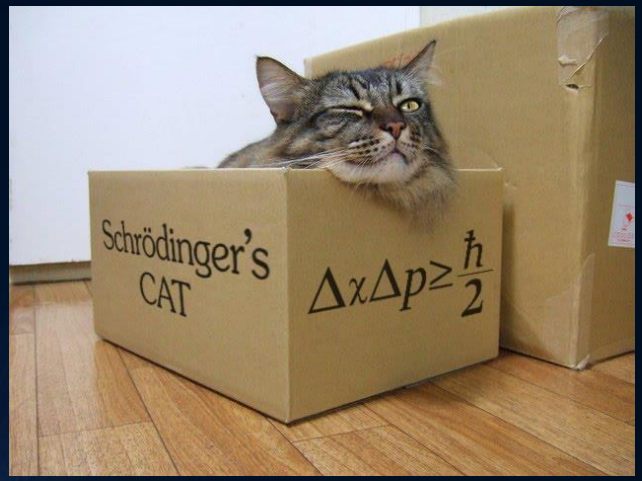
Antena

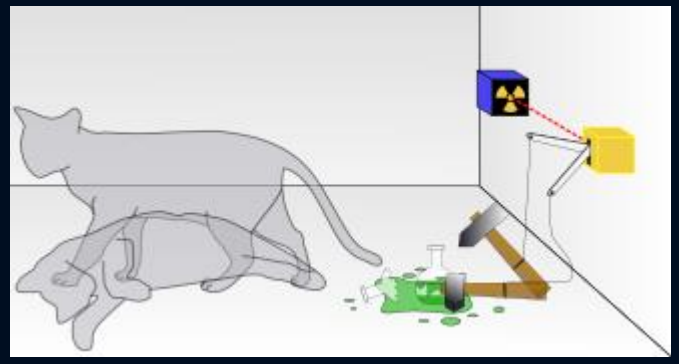


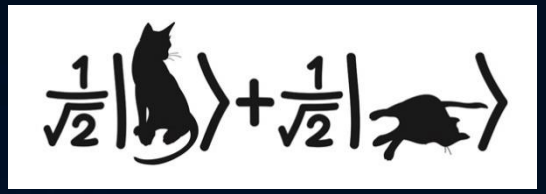
- Difrakcija



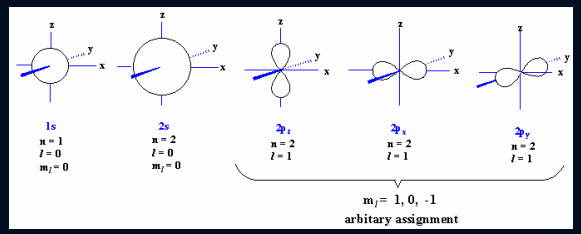
Kvantna teorija

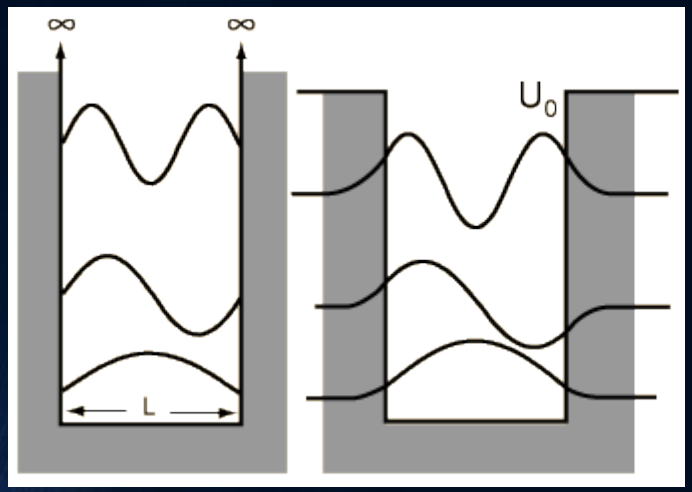


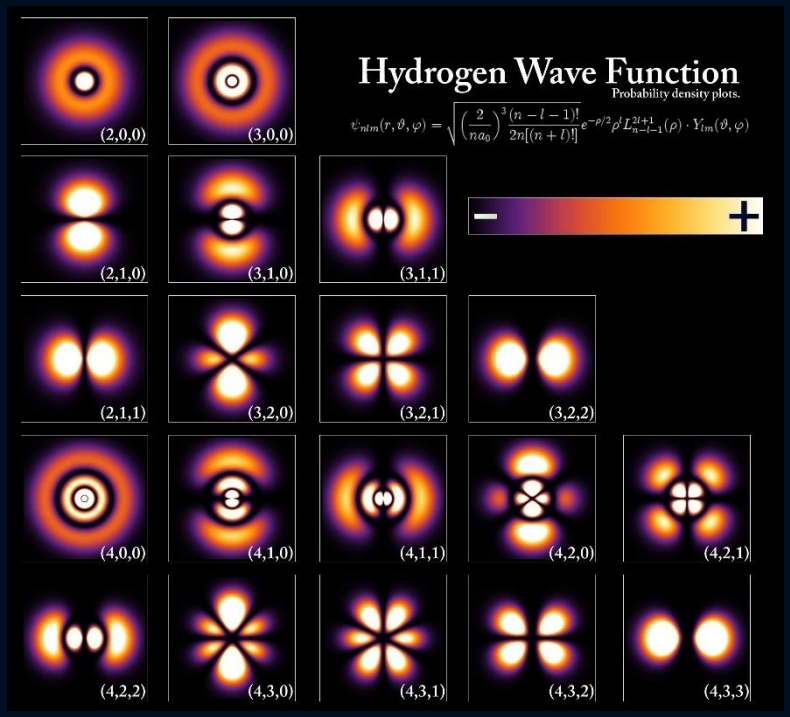


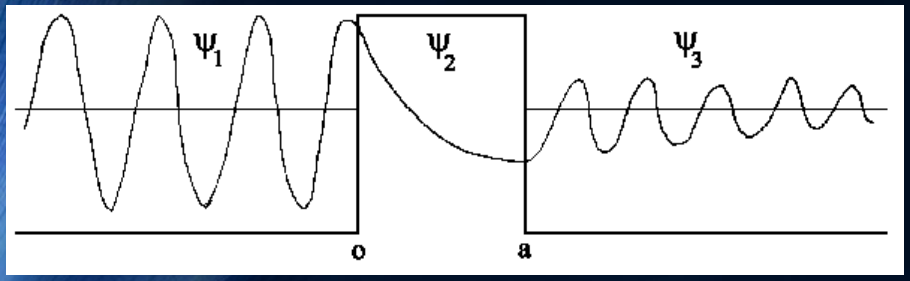


Kvantna teorija

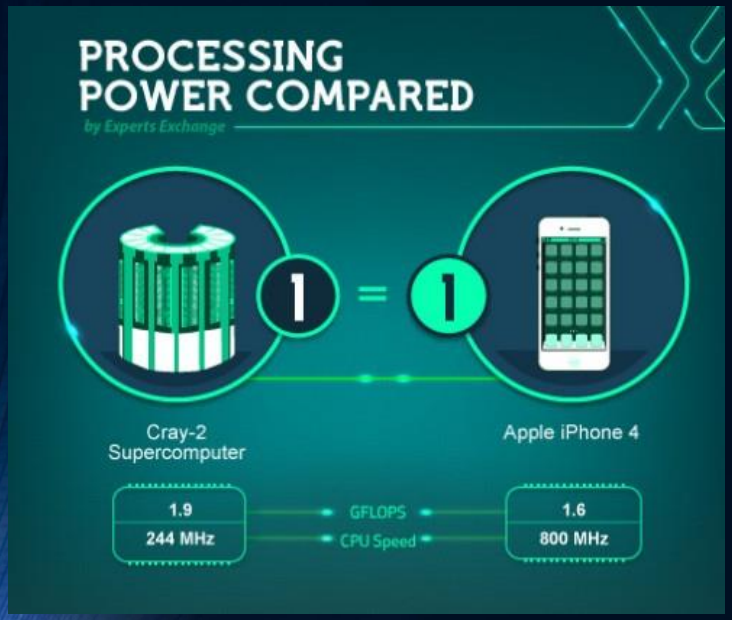








Kompjuterska snaga



1985 - 1990

Today's SmartPhones are smart…

With more computing power than Apollo 11 in the pockets of many students, we could take advantage of these devices in science class!

Apollo 11 Moon Landing image taken from http://history.nasa.gov/ap11ann/kippsphotos/apollo.html

SMART telefoni (senzori...)

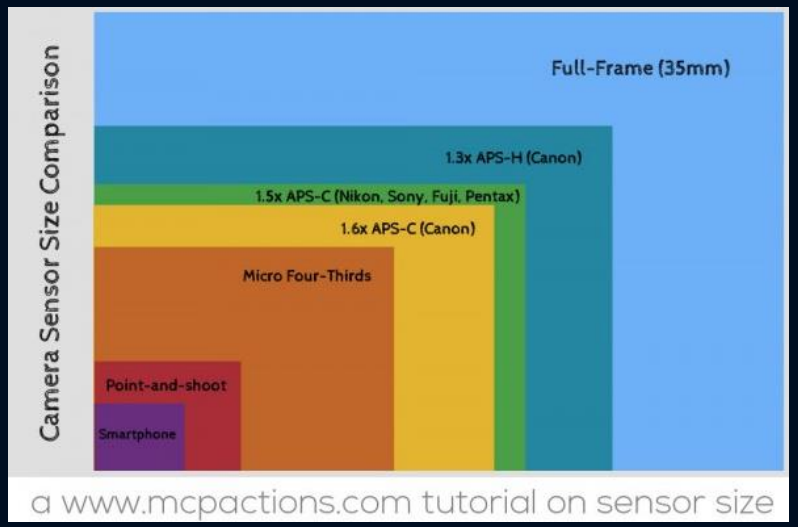
Malo zabave


ANGRY BIRDS


Selfie (n.):
a picture taken of a person
by that person


iPod
2:43 PM

Fotografija

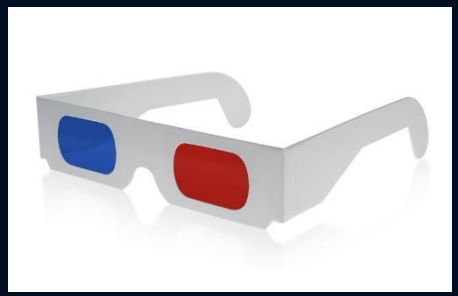


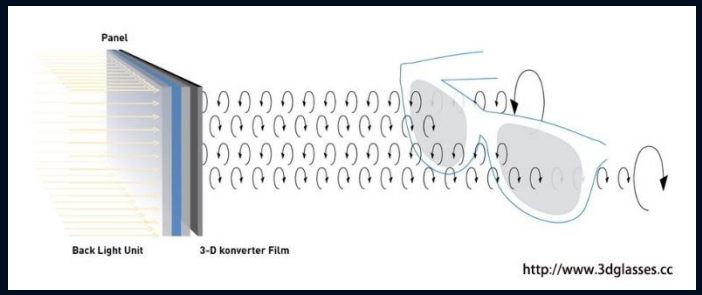
3D fotografije

- Lako je „zbuniti“ oko i mozak
- Levo i desno oko vide sliku koja se malo razlikuje
- „Obradom“ ovih slika mozak stvara sliku 3D prostora
- Ako iskoristimo ovo i svakom oku prikažemo po jednu (2D) fotografiju koje su snimljene malim pomeranjem aparata videćemo 3D fotografiju

3d fotografije

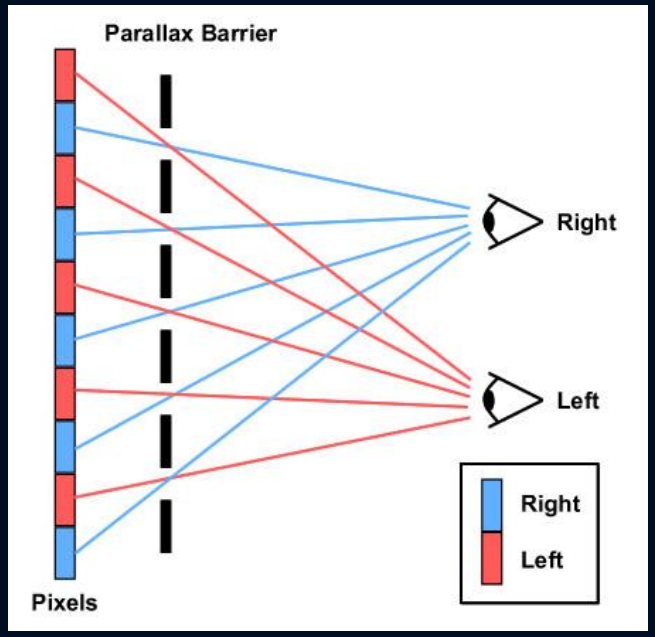
- 3D fotografije na različite načine:
  - Plavo/crvene naočare
  - Polarizacione naočare
  - VR naočare

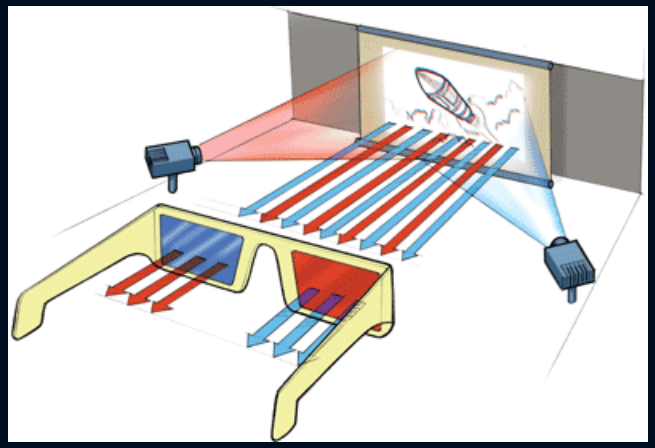


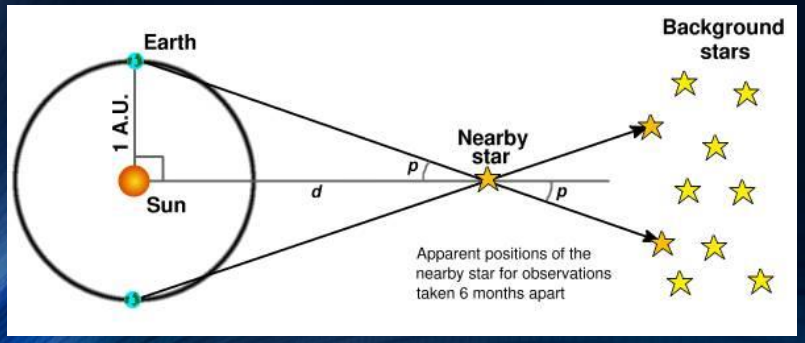


3d fotografije

- Princip rada je isti, različita realizacija
  - Odgovarajući filter (boja, polarizacija, sočivo/pregrada) selektuju sliku koja dolazi do levog a koja do desnog oka
  - Istovremenim posmatranjem ove dve fotografije mozak rekonstruiše realan 3D svet
  - Efekat koji je sličan paralaksi







Kako snimiti i gledati

- Šta je potrebno:
  - Fotoaparat ili mobilni telefon
  - VR naočare ili crveno/plave naočare (možete lako da ih napravite – potrebno je samo staklo ili plastika u odgovarajućoj boji ili flomasteri da obojite belu, providnu plastiku)
- Kako:
  - Snimite prvu fotografiju, pomerite malo aparat i snimite drugu, sličnu fotografiju
  - Za VR naočare stavite fotografiju jednu pored druge, za plavo/crvene naočare potreban je program za konverziju (ima ih puno, „googlajte" reč analygraph ☺

Analygraph
Za plavo/crvene naočare

http://instantsolve.net/anaglyph/

Google Play Make It 3D

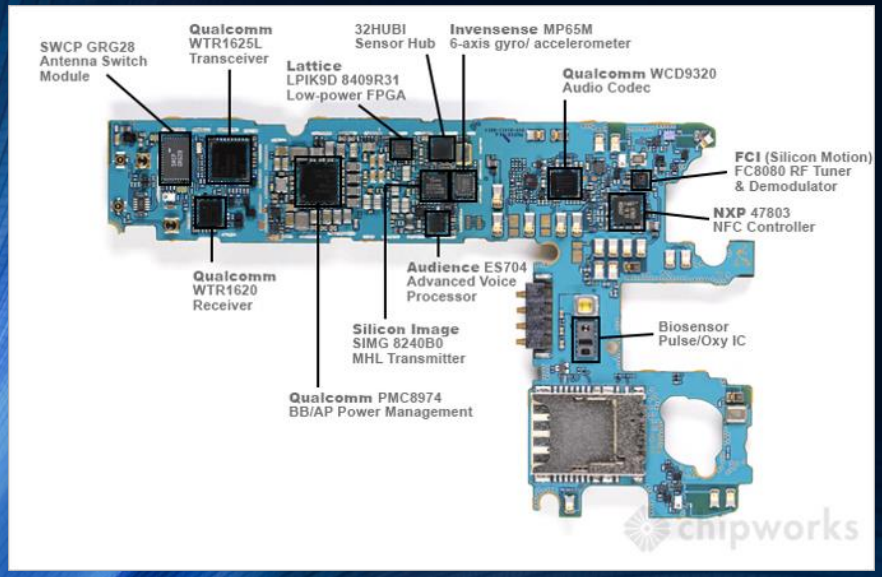
Za VR ili Google Cardboard naočare

Proširena stvarnost

- eng. *Augmented reality*

Senzori

- 2010 – Galaxy S
- 2011 – Galaxy SII
- 2012 – Galaxy SIII
- 2013 – Galaxy S4
- 2014 – Galaxy S5

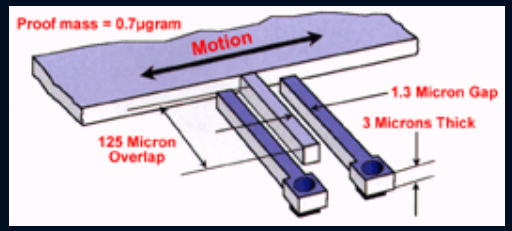


Šta su uopšte to senzori?

- Uređaj koji meri neku fizičku veličinu i rezultat konvertuje u signal koji može da pročita posmatrač ili mašina
- Svaki dan: termometar, otvaranje vrata, kamere, GPS
- I u najstarijim telefonima: mikrofon, tasteri
- Pametni telefoni: tač ekrani, žiroskop, GPS, ubrzanje, kamera

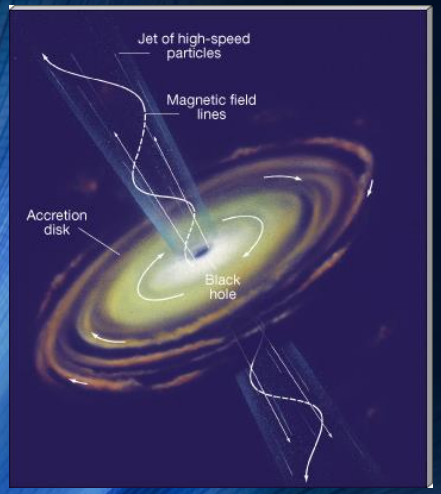
Vrste senzora

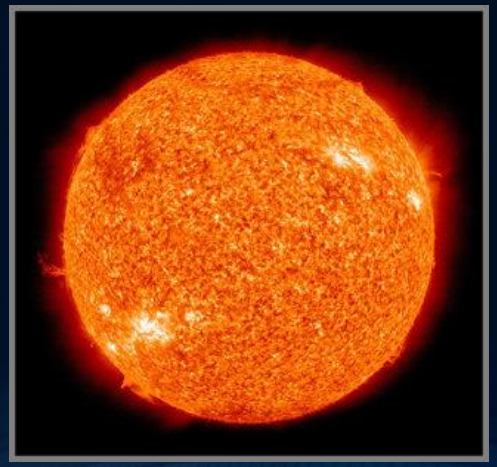
- Rastojanje
  - IC predajnik i prijemnik; meri koliko svetlosti se vrati
  - Nema mnogo IC izvora pa nema ni smetnji
  - Merenje brzine i rastojanja (laseri, mikrotalasi itd)
  - Sličan princip: ultrazvučni senzori – sonar

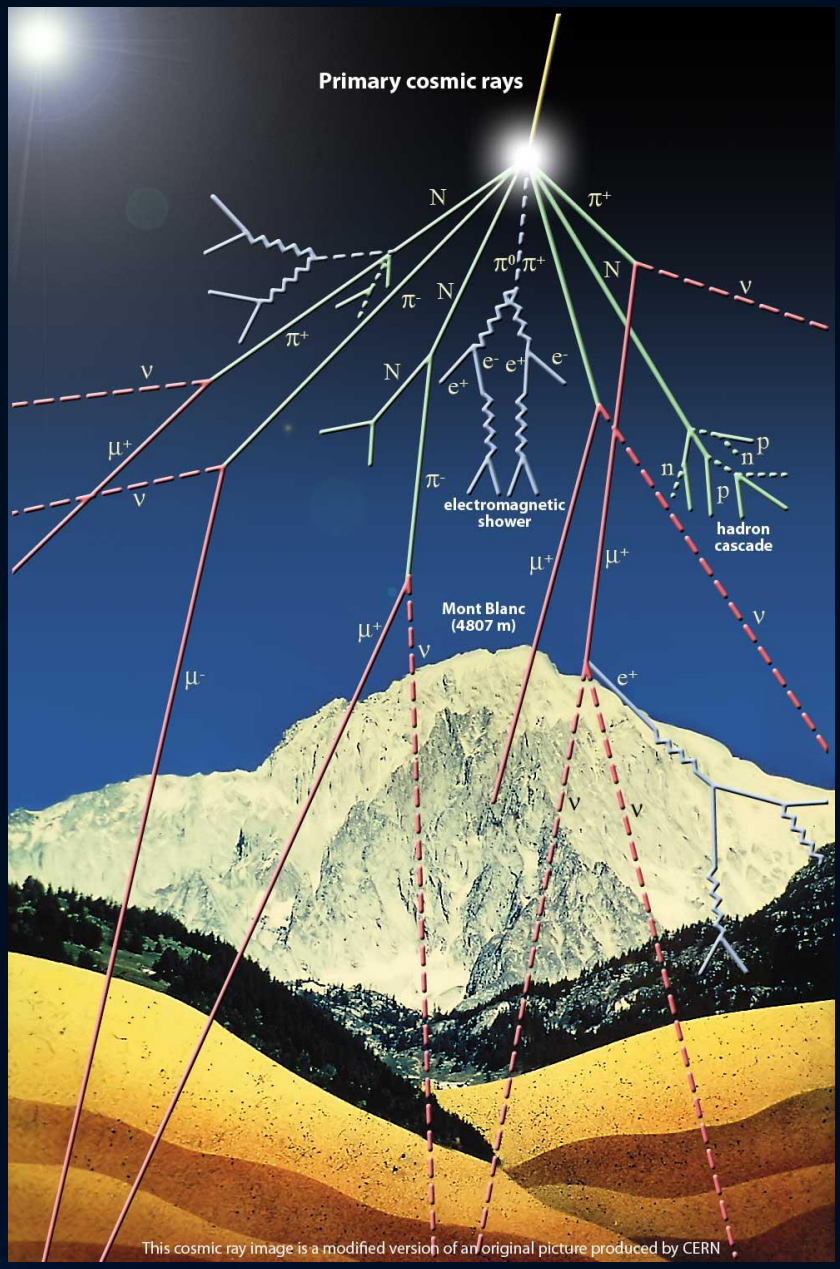


- Ubrzanje i žiroskop
  - Promena brzine u 2 ili 3 prostorne dimenzije
  - Meri se brzina promena kapaciteta kondenzatora i prevodi u ubrzanje
  - Žiroskop – koriolisova sila: kreće duž jedne ose, rotira duž druge, javlja se sila duž treće ose

Kosmičko zračenje

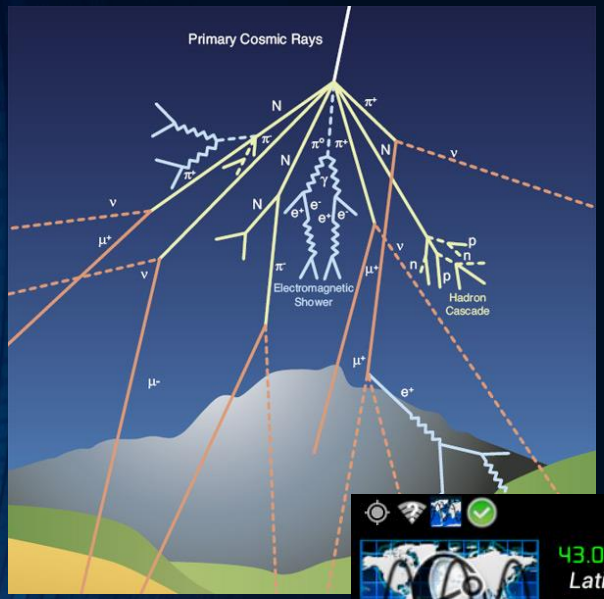






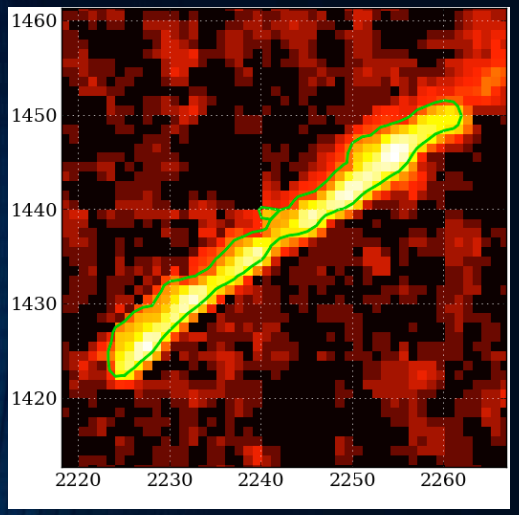
Projekat DECO

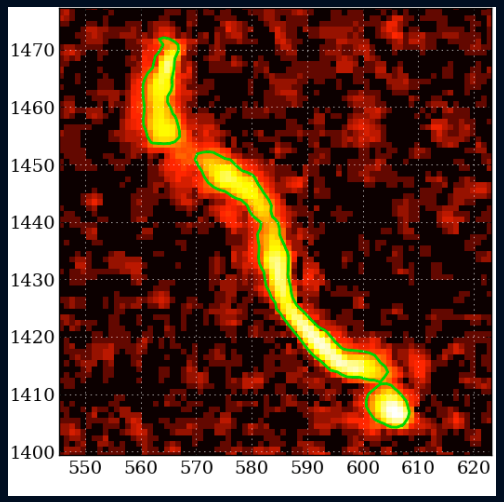
DECO
Distributed Electronic Cosmic-ray Observatory

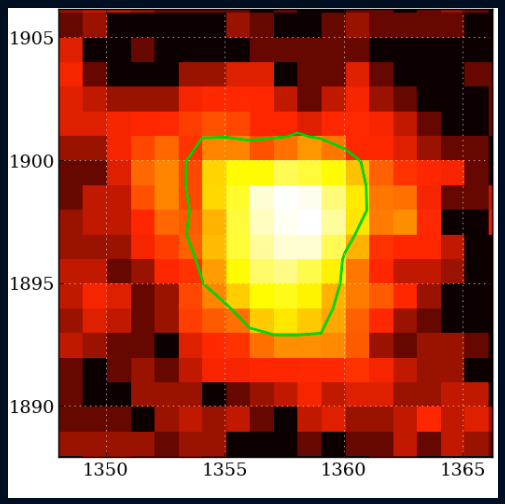


- Snima fotografije 1-2 sekunde
- Dovoljno sjajnih piksela – kandidat
- Nova analiza – proverava događaj
- Kosmičko zračenje – mioni
  - Drugi događaji: elektroni, gama zraci, alfa čestice (radioaktivno zračenje okoline)
- Nekoliko događaja za 24h

Projekat DECO - događaji







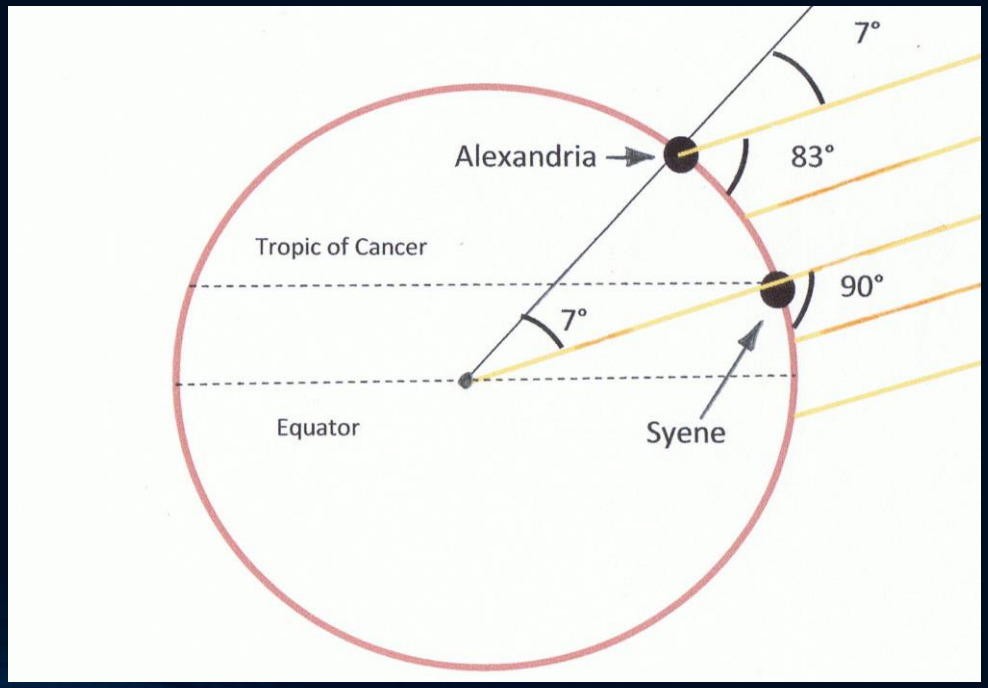
- Mion, kosmičko zračenje
- Elektron (radioaktivno zračenje, direktno ili gama zračenje koje je “pogodilo” elektron)
- Elektron ili gama zračenje

Navigacija – na nebu

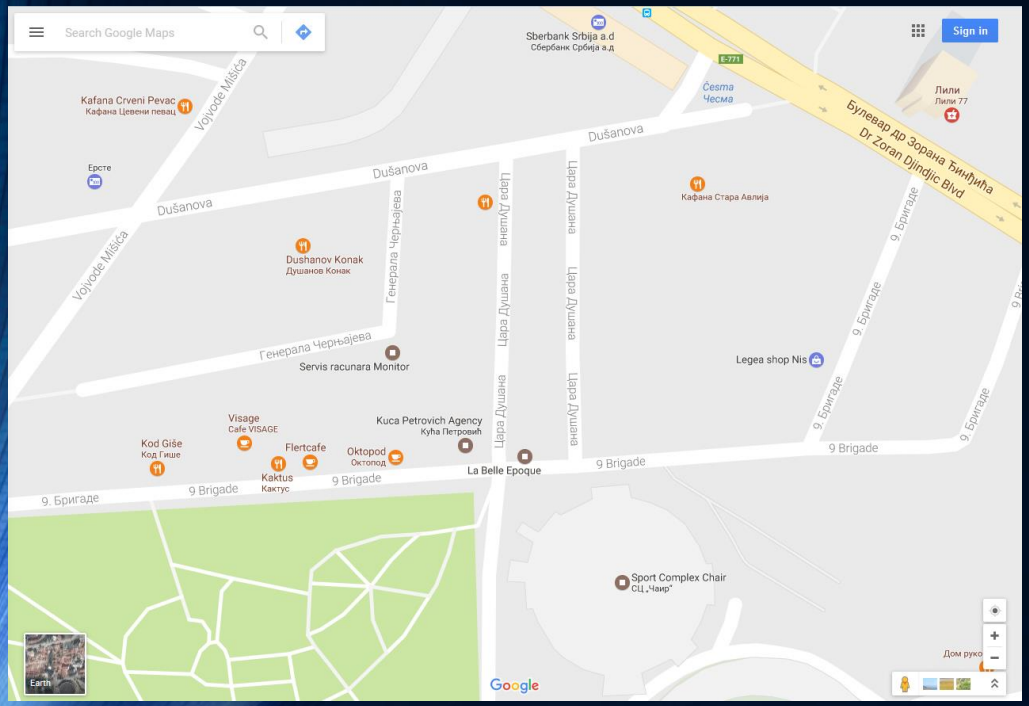
A sada - rešenje

Obim Zemlje

- Eratosten (276 p.n.e. - 194 p.n.e.)
- Sijena – prvi dan leta, u podne, Sunce tačno iznad
- Aleksandrija – senka!
- Razlika – 7°
- Rastojanje 7/360°



Ili mobilni telefon & Google Map ☺



$$\phi_1 = 43.317254$$
$$\phi_2 = 43.318517$$

$$\Delta\phi = \left|\phi_1 - \phi_2\right| = 0.001263$$
$$s = 150\text{m}$$

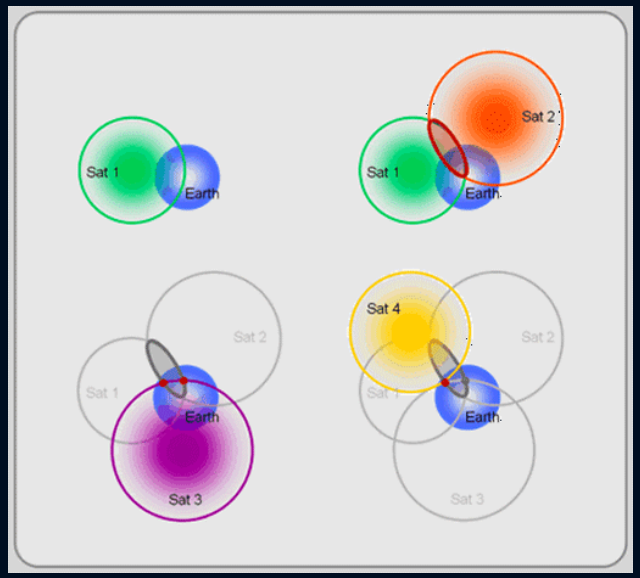
$$L = 2\pi R = \frac{360^o \cdot s}{\phi} \approx 42755,3\text{km}$$
$$R = 6800\text{km}$$

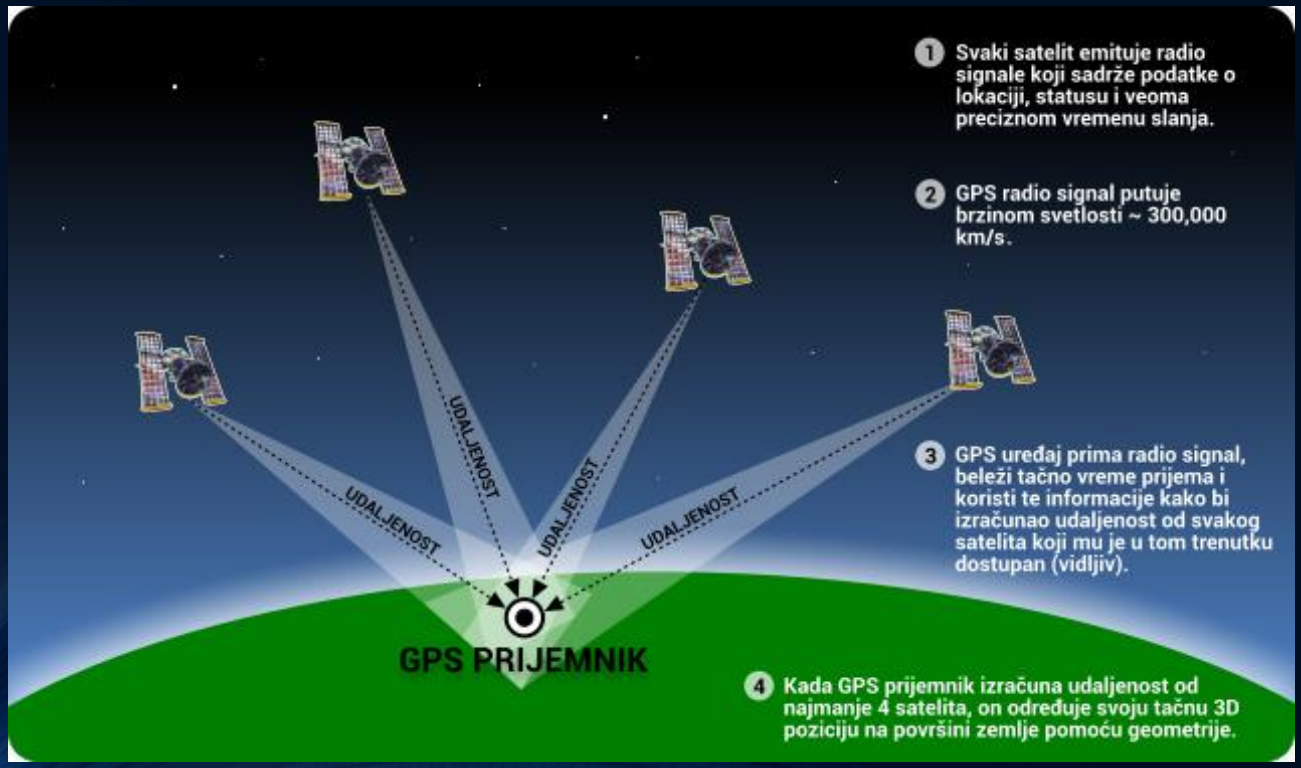
Navigacija – na Zemlji

Globalni pozicioni sistem (GPS)

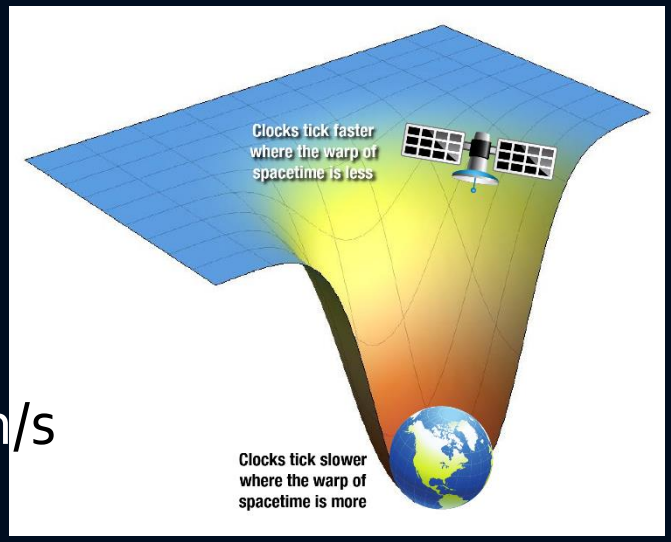
- Tri sistema:
  - U vasioni, Kontrolni, Korisnički
- Blok I – lansirani 1978-85, svi van funkcije
- Blok II – 24 GPS satelita, 6 orbitalnih ravni, ravnomerno raspoređeni i nagnutih pod uglom od 55 u odnosu na ekvatorijalnu ravan – NE rotiraju
- Svaka orbita po 4 satelita, skoro kružne; prečnik 4 puta veći od prečnika Zemlje
- Stanice za praćenje: Havaji, Kolorado, Kvajlin ostrvo, Aknezijsko ostrvo; ažuriranje dva puta dnevno

Globalni pozicioni sistem (GPS)





Ajnštajn i GPS



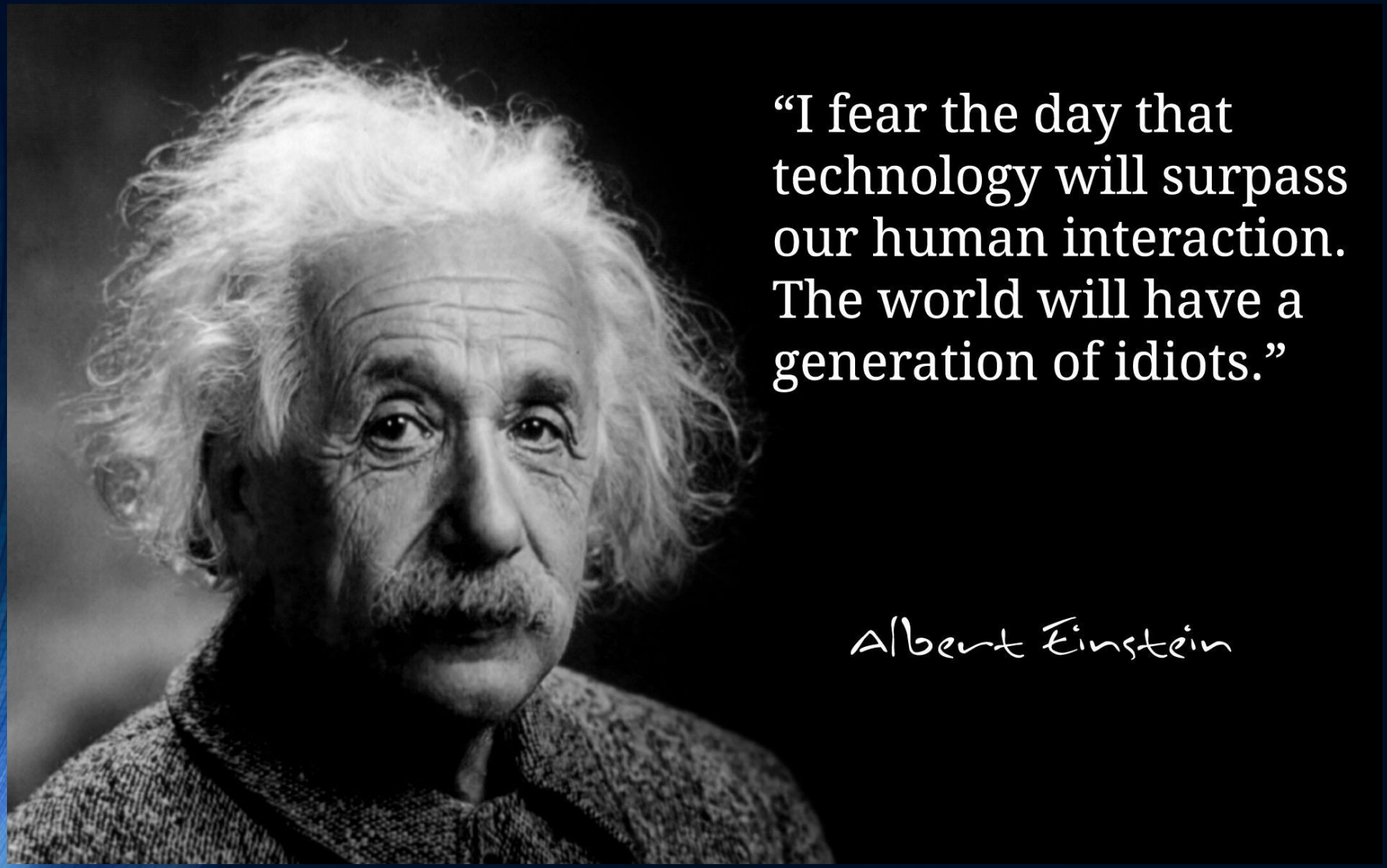
- Visina: 20000 km, brzina 14000 km/s
- Svaki satelit – atomski časovnik:
  - Impuls sa tačnošću od 1 nanosekunde
- Položaj određuje sa tačnošću od 5-10 m (20-40 ns)
- VREME JE RELATIVNO ! ! !
  - STR: 7 mikrosekundi sporije na dan (na satelitu)
  - GTR: 45 mikrosekundi sporije na dan (na Zemlji)
- Bez teorije relativnosti GPS bi postao neupotrebljiv posle samo 2 minuta! (greška 38000 ns /dan)

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

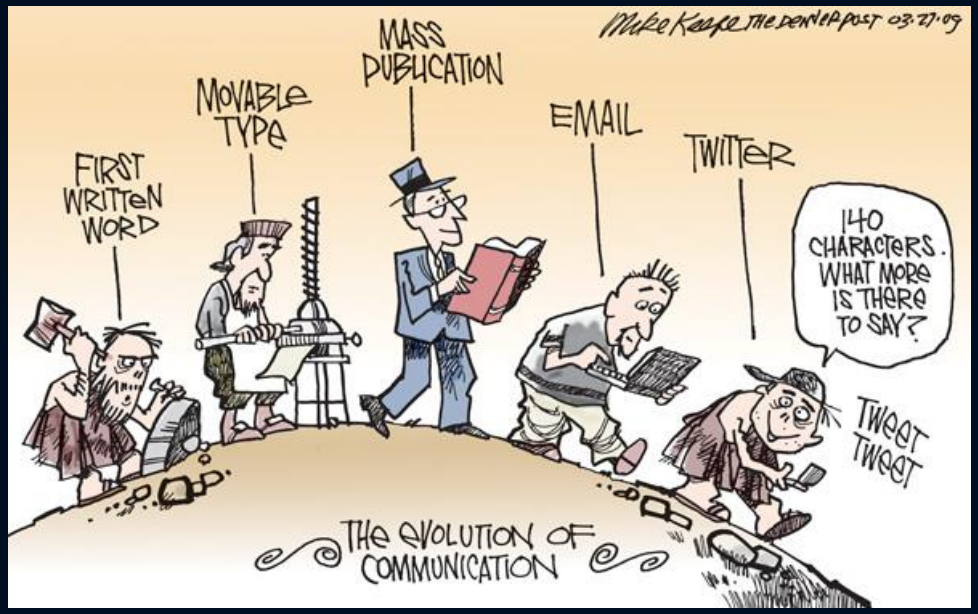
$$T = \frac{T_0}{\sqrt{1 - \frac{2GM}{Rc^2}}}$$

$$1s = 10^3 \mathrm{ms} = 10^6 \mu\mathrm{s} = 10^9 \mathrm{ns}$$

$$1s = 1000ms = 1.000.000\mu\mathrm{s} = 1.000.000.000\mathrm{ns}$$


“I fear the day that technology will surpass our human interaction. The world will have a generation of idiots.”
Albert Einstein

Šta je telefon zamenio?



www.svetnauke.org
mmilan@svetnauke.org
www.facebook.com/svetnauke.org