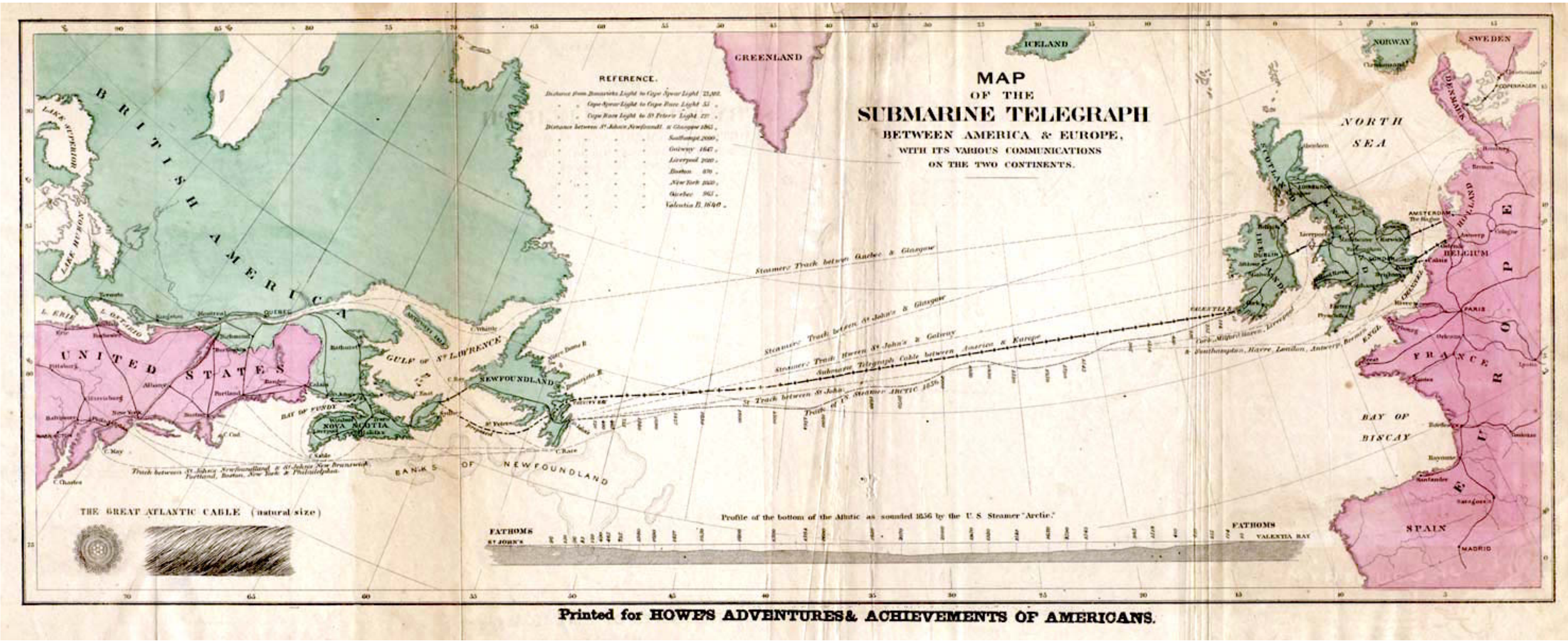
Linee di trasmissione

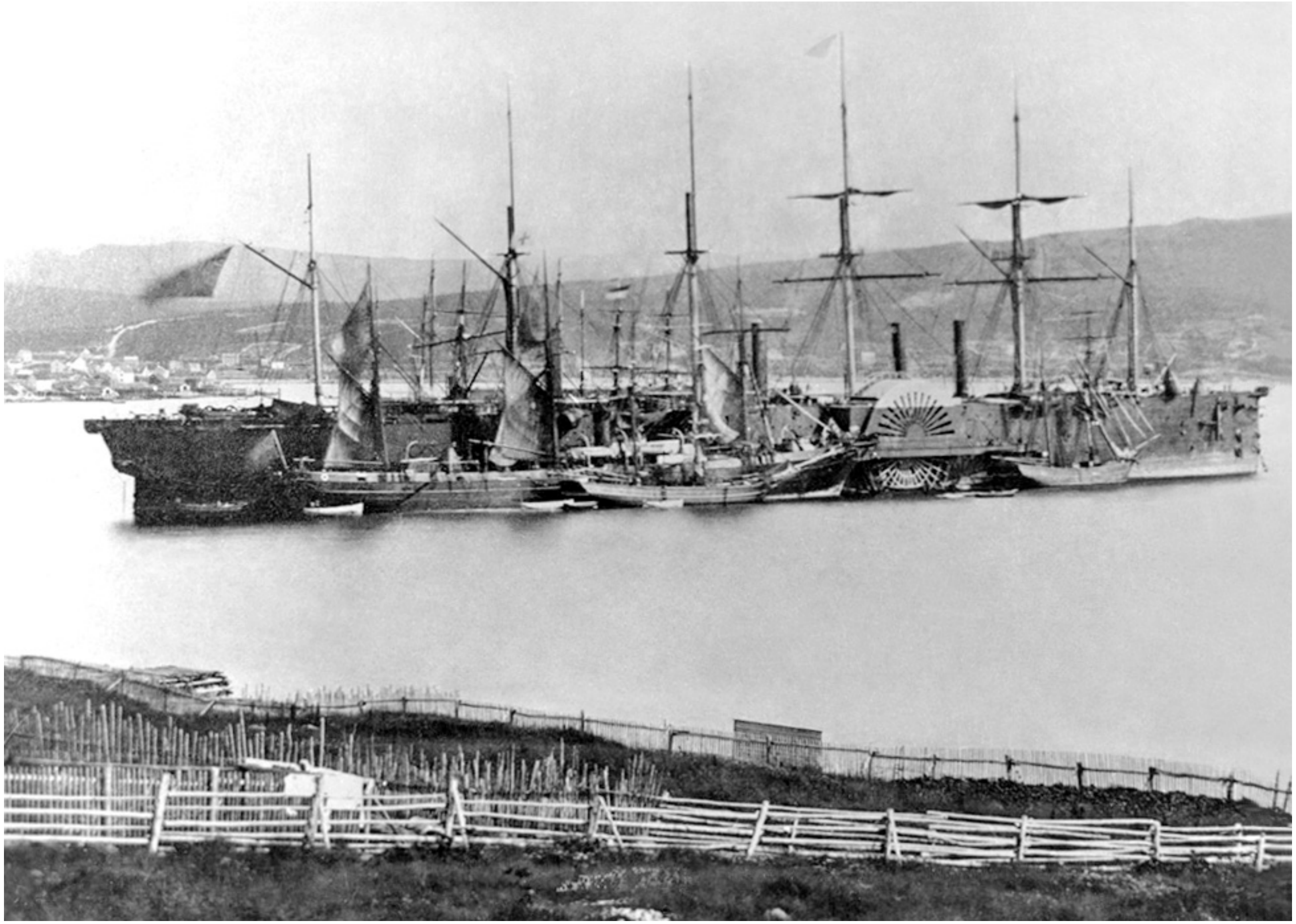
Edoardo Milotti

Corso di Fondamenti Fisici di Tecnologia Moderna

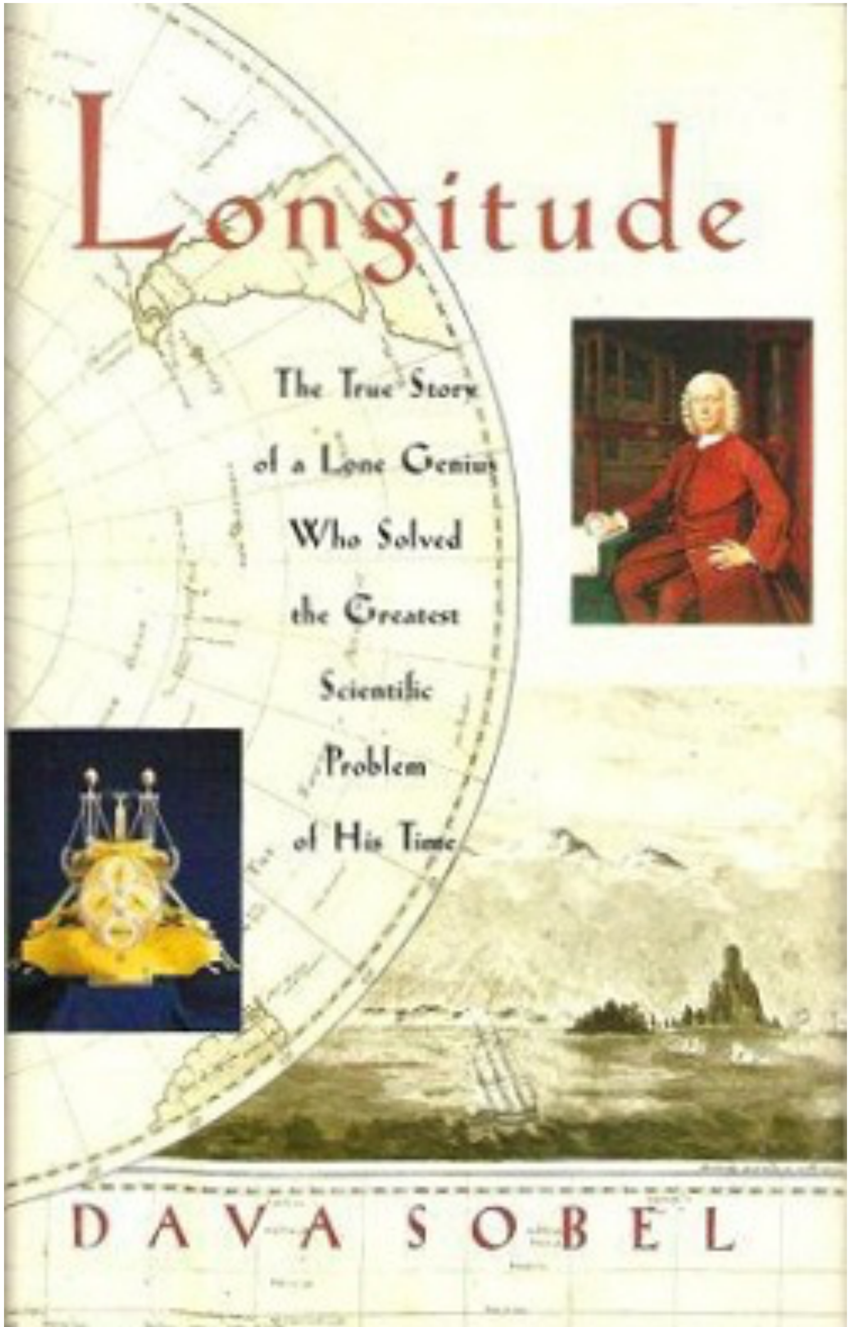
A.A. 2020-21



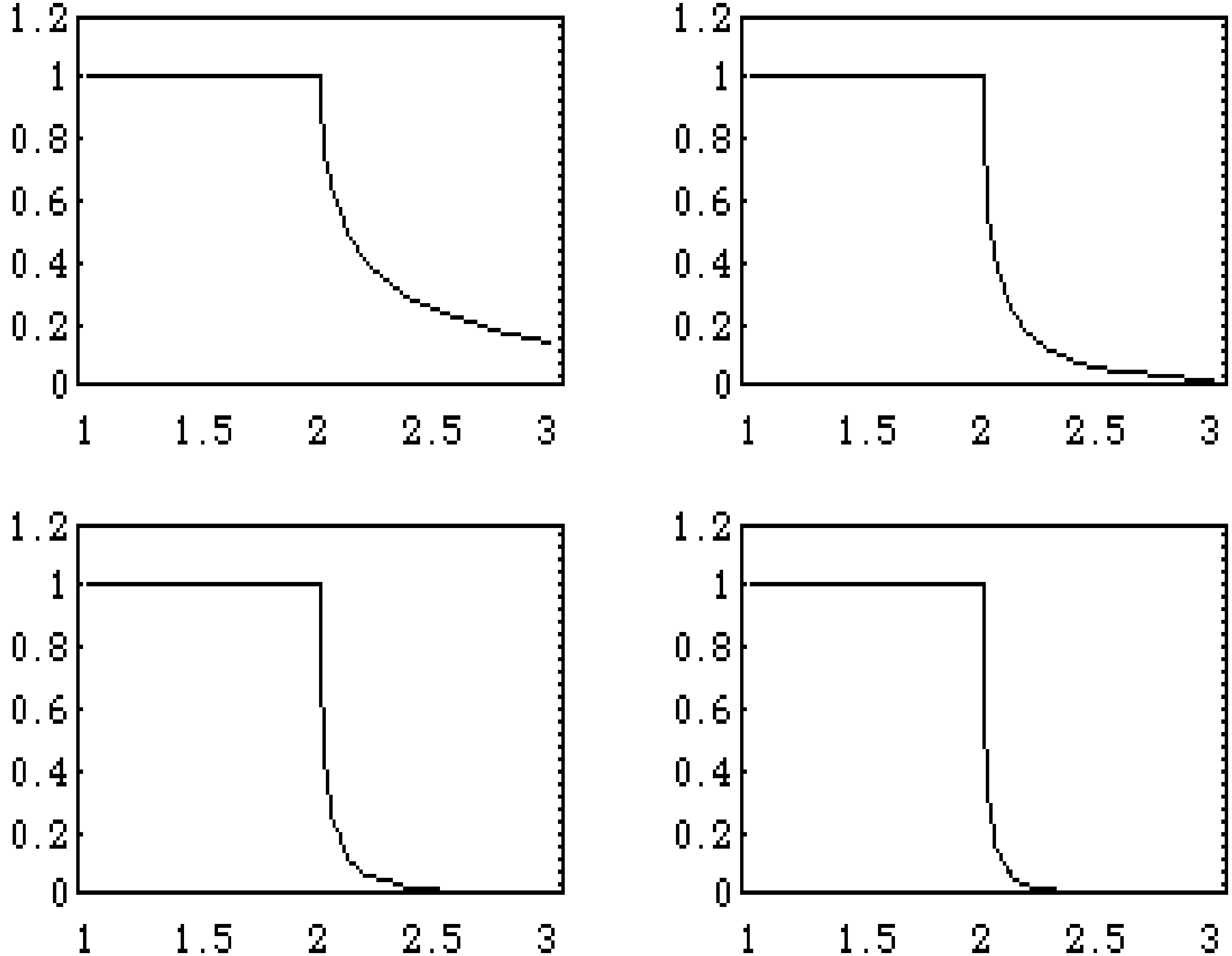
Map of the 1858 trans-Atlantic cable route



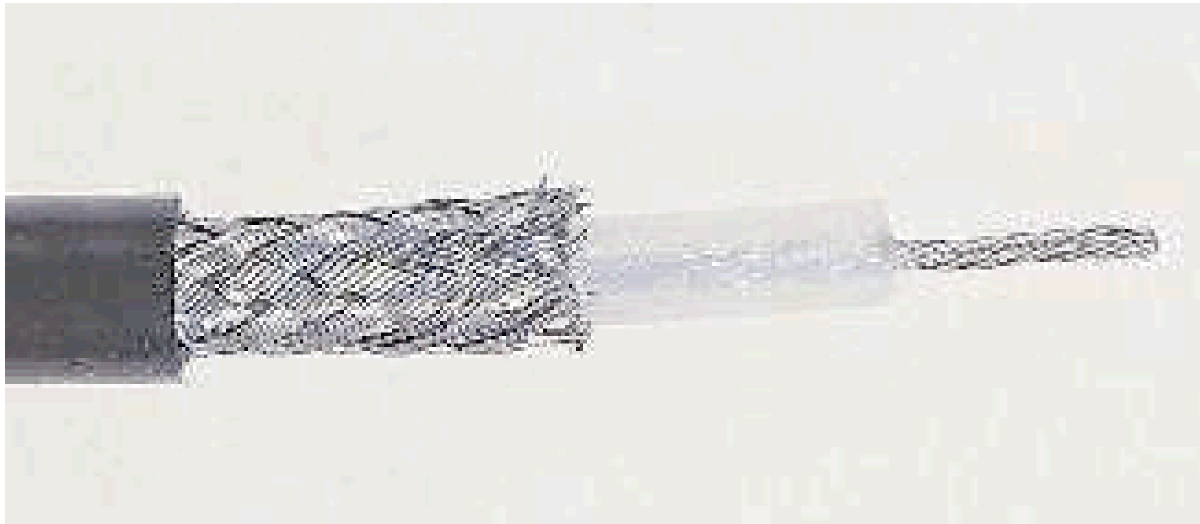
Great Eastern at Heart's Content



Il cronometro di John Harrison

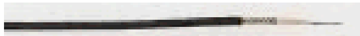


1.2
1
0.8
0.6
0.4
0.2
0
1
1.5
2
2.5
3

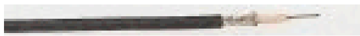


Un cavo coassiale RG58/CU, con conduttori in rame stagnato, isolato con polietilene (PET) e con guaina esterna in polivinilcloruro (PVC) nero.

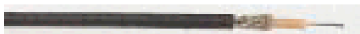
Cavo coassiale CLFH-178



Cavo coassiale CLFH-179

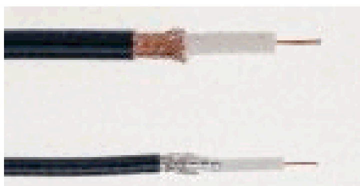


Cavo coassiale CLFH-316



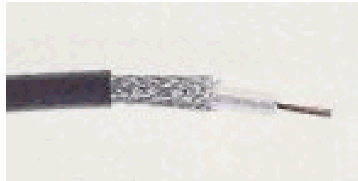
Cavo coassiale CLFH-400

Cavo coassiale RG 6/U



Cavo coassiale RG-75 miniatura colorati

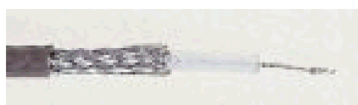
Cavo coassiale RG174A/U



Cavo coassiale RG178B/U

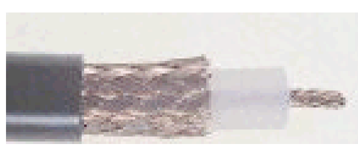
Cavo coassiale RG178PE

Cavo coassiale RG179B/U

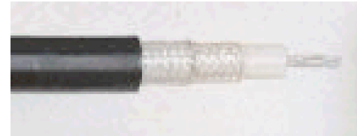


Cavo coassiale RG179PE

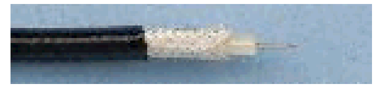
Cavo coassiale RG213/U



Cavo coassiale RG214/U



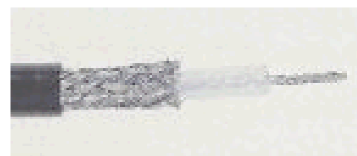
Cavo coassiale RG223/U



Cavo coassiale RG316/U

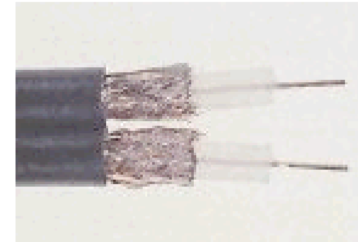
Cavo coassiale RG58 CU

Cavo coassiale RG58C/U



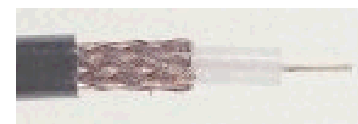
Cavo coassiale RG58C/U LSF

Cavo coassiale RG59 doppio

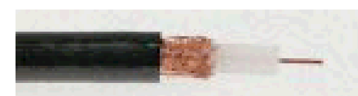


Cavo coassiale RG59 miniatura

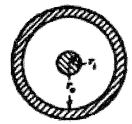
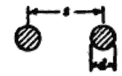
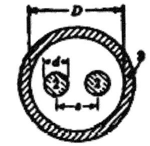
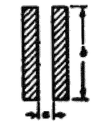
Cavo coassiale RG59B/U



Cavo coassiale RG59B/U LSF



Cavo coassiale RG62 miniatura

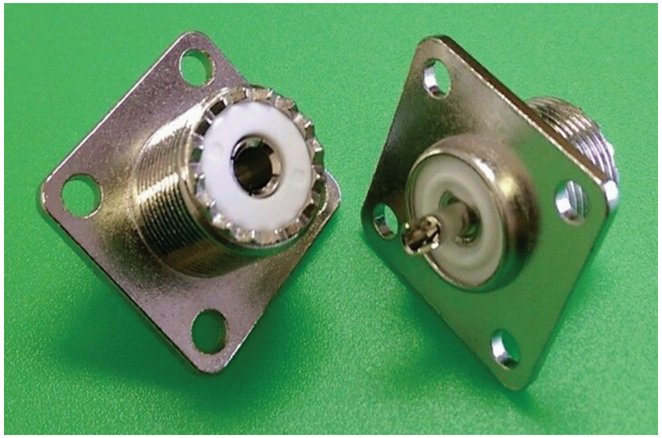
			$p = \frac{s}{d}$ $q = \frac{s}{D}$ 	 Formulas for $a \ll b$
Capacitance C, farads/meter	$\frac{2\pi\epsilon}{\ln\left(\frac{r_0}{r_i}\right)}$	$\frac{\pi\epsilon}{\cosh^{-1}\left(\frac{s}{d}\right)}$	----	$\frac{\epsilon b}{a}$
External inductance L, henrys/meter	$\frac{\mu}{2\pi}\ln\left(\frac{r_0}{r_i}\right)$	$\frac{\mu}{\pi}\cosh^{-1}\left(\frac{s}{d}\right)$	----	$\mu\frac{a}{b}$
Conductance G, siemens/meter	$\frac{2\pi\sigma}{\ln\left(\frac{r_0}{r_i}\right)} = \frac{2\pi\omega\epsilon''}{\ln\left(\frac{r_0}{r_i}\right)}$	$\frac{\pi\sigma}{\cosh^{-1}\left(\frac{s}{d}\right)} = \frac{\pi\omega\epsilon''}{\cosh^{-1}\left(\frac{s}{d}\right)}$	----	$\frac{\sigma b}{a} = \frac{\omega\epsilon'' b}{a}$
Resistance R, ohms/meter	$\frac{R_s}{2\pi}\left(\frac{1}{r_0}+\frac{1}{r_i}\right)$	$\frac{2R_s}{\pi d}\left[\frac{s/d}{\sqrt{(s/d)^2-1}}\right]$	$\frac{2R_{s2}}{\pi d}\left[1+\frac{1+2p^2}{4p^4}(1-4q^2)\right] + \frac{8R_{s3}}{\pi D}q^2\left[1+q^2-\frac{1+4p^2}{8p^4}\right]$	$\frac{2R_s}{b}$
Internal inductance L_i, henrys/meter (for high frequency)	← $\frac{R}{\omega}$ →			
Characteristic impedance at high frequency Z_0, ohms	$\frac{\eta}{2\pi}\ln\left(\frac{r_0}{r_i}\right)$	$\frac{\eta}{\pi}\cosh^{-1}\left(\frac{s}{d}\right)$	$\frac{\eta}{\pi}\left\{\ln\left[2p\left(\frac{1-q^2}{1+q^2}\right)\right] - \frac{1+4p^2}{16p^4}(1-4q^2)\right\}$	$\eta\frac{a}{b}$
Z_0 for air dielectric	$60\ln\left(\frac{r_0}{r_i}\right)$	$120\cosh^{-1}\left(\frac{s}{d}\right) \cong 120\ln\left(\frac{2s}{d}\right)$ if $s/d \gg 1$	$120\left\{\ln\left[2p\frac{(1-q^2)}{(1+q^2)}\right] - \frac{1+4p^2}{16p^4}(1-4q^2)\right\}$	$120\pi\frac{a}{b}$
Attenuation due to conductor α_c	← $\frac{R}{2Z_0}$ →			
Attenuation due to dielectric α_d	← $\frac{GZ_0}{2} = \frac{\sigma\eta}{2} = \frac{\pi}{\lambda}\left(\frac{\epsilon''}{\epsilon'}\right)$ →			
Total attenuation dB/meter	← $8.686(\alpha_c+\alpha_d)$ →			
Phase constant for low-loss lines β	← $\omega\sqrt{\mu\epsilon'} = \frac{2\pi}{\lambda}$ →			

All units above are mks.

$\epsilon = \epsilon' - j\epsilon''$ = permittivity, farads/meter
μ = permeability, henrys/meter } for the dielectric
$\eta = \sqrt{\mu/\epsilon}$ ohms

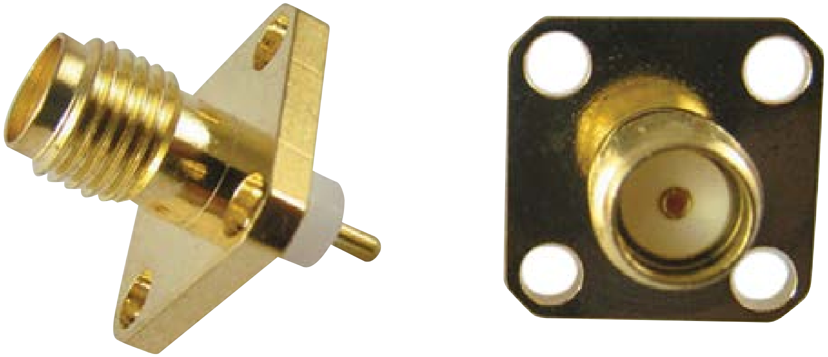
ϵ'' = loss factor of dielectric = σ/ω
R_s = skin effect surface resistivity of conductor, ohms
λ = wavelength in dielectric

Formulas for shielded pair obtained from Green, Leibe, and Curtis, *Bell System Tech. Journ.*, 15, pp. 248–284 (April 1936).



1. The UHF connector can still be purchased from some manufacturers today.

3. The BNC connector is often found in test instruments.



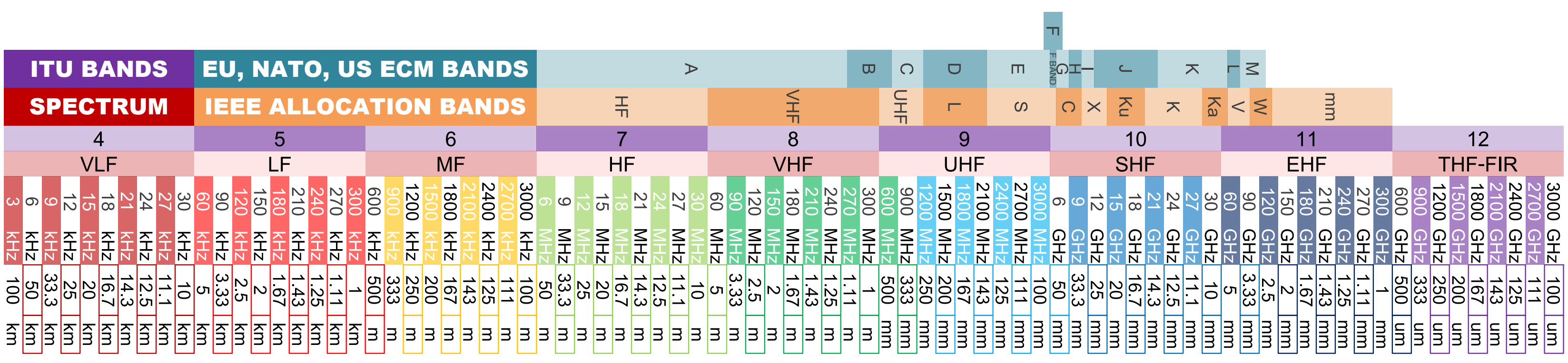
1. The SMA connector is one of the most common connector types used for RF/microwave applications.

references&tools

CONNECTOR FREQUENCIES:

Coaxial Connectors

Coaxial Designations	Maximum Frequency	Visual Guage
1mm	110 GHz	
1.85mm	67 GHz	
MINI SMP • V	60 GHz	
2.4mm	50 GHz	
GPO • OSMP • OS-50P	40 GHz	
2.92mm • K • SMP	40 GHz	
SSMA	38 GHz	
3.5mm-P	34 GHz	
OSSP	28 GHz	
SMA-P • 3.5mm	26.5 GHz	
OSP	22 GHz	
N-P • TNC-P • ZMA-P	18 GHz	
SMA • APC-7 • 7mm • QMA	18 GHz	
SSMB • ZMA	12.4 GHz	
C • SC • N • TNC	11 GHz	
1.0/2.3 • SMC	10 GHz	
GR874	9 GHz	
MCX-75 • UMCX • 7/16 • OSMT	6 GHz	
MMCX • OSX • PCX • MCX	6 GHz	
HN • SMB • FAKRA	4 GHz	
BNC • SMB-75 • MINI SMB-75	4 GHz	
F	3 GHz	
MINI UHF	2.4 GHz	
10-32	2 GHz	
N-75	1.5 GHz	
LC • 1.6/5.6	1 GHz	
BNC-75 • TNC-75	1 GHz	
UHF	300 MHz	
TWINAX - FME	200 MHz	
BNC TWINAX	100 MHz	



Applicazioni: filtri strip line

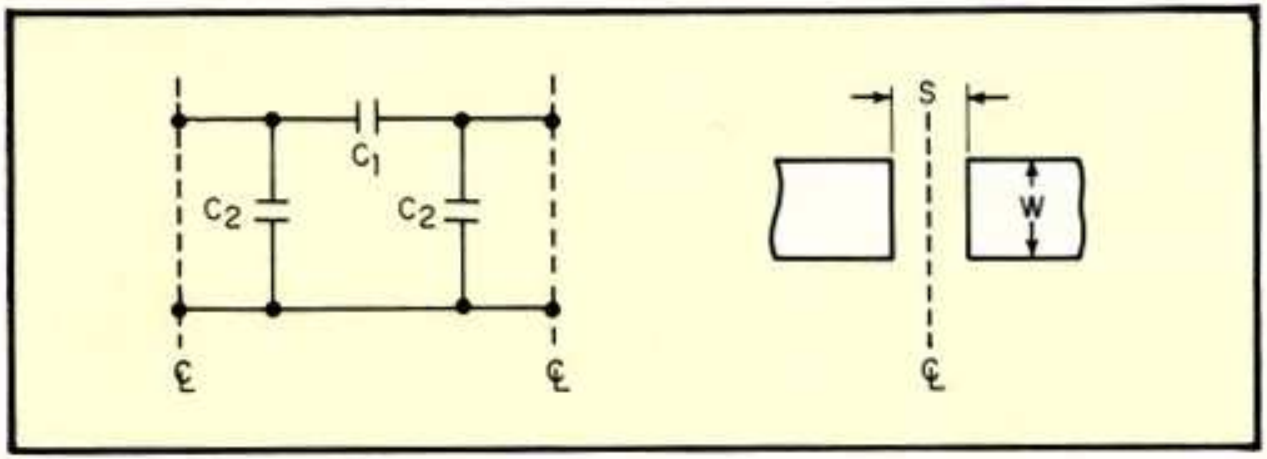


Fig. 4. Equivalent circuit of series gap in strip line (center line representation).