Dielectric Properties of Materials

Rees discusses 4 categories of materials based on properties of their dielectric constant:

1) non-polar material
   \[ \varepsilon' \text{ and } \varepsilon'' \text{ are constant with } \omega. \]

2) polar material (water)
   \[ \varepsilon' \text{ and } \varepsilon'' \text{ vary with } \omega \text{ following the Debye equation.} \]

3) conductive (salt water, copper)
   \[ \varepsilon'' = \frac{\sigma}{\varepsilon_0 \omega} \]

4) plasma (ionosphere)
   \[ \varepsilon = n^2 = 1 - \frac{Ne^2}{\varepsilon_0 m \omega^2} \]
   \[ N \text{- electron density} \]
   \[ m \text{- electron mass} \]
   \[ e \text{- electron charge} \]

For a plasma if \( n > 0 \) the waves are slowed as they travel through the ionosphere. If \( n < 0 \), \( n \) is purely imaginary and all the energy is reflected off the ionosphere. Under typical ionospheric conditions, low-frequency radio waves reflect while higher frequency microwaves can propagate through. Since the ionosphere is dispersive (i.e. speed depends on \( \omega \)) a dual frequency microwave instrument (a radar altimeter or GPS) can measure the total electron content of a column of ionosphere and can use this to correct for the delay along the path of one or both frequencies.
Fig. 7.9 The index of refraction (top) and absorption coefficient (bottom) for liquid water as a function of linear frequency. Also shown as abscissas are an energy scale (arrows) and a wavelength scale (vertical lines). The visible region of the frequency spectrum is indicated by the vertical dashed lines. The absorption coefficient for sea water is indicated by the dashed diagonal line at the left. Note that the scales are logarithmic in both directions. (after Jackson, J.D., Classical Electrodynamics, John Wiley and Sons, 1975)
The ionosphere is a shell of electrons and electrically charged atoms and molecules that surrounds the Earth, stretching from a height of about 50 km to more than 1000 km. It owes its existence primarily to ultraviolet radiation from the sun.
Data from over 100+ continuously operating GPS receivers in a global network are being used to produce global maps of the ionosphere's total electron content (TEC). These Global Ionosphere Maps (GIM) provide instantaneous "snapshots" of the global TEC distribution, by interpolating, in both space and time, the 6-8 simultaneous TEC measurements obtained from each GPS receiver every 30 seconds. The maps can be produced unattended in a real-time mode, with an update rate of 5-15 minutes.
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Activity cycles 21, 22 and 23 seen in sunspot number index, TSI, 10.7cm radio flux, and flare index. The vertical scales for each quantity have been adjusted to permit overplotting on the same vertical axis as TSI. Temporal variations of all quantities are tightly locked in phase, but the degree of correlation in amplitudes is variable to some degree. [Wikipedia]
May 8, 2009 -- The Solar Cycle 24 Prediction Panel has reached a consensus decision on the prediction of the next solar cycle (Cycle 24). First, the panel has agreed that solar minimum occurred in December, 2008. This still qualifies as a prediction since the smoothed sunspot number is only valid through September, 2008. The panel has decided that the next solar cycle will be below average in intensity, with a maximum sunspot number of 90. Given the predicted date of solar minimum and the predicted maximum intensity, solar maximum is now expected to occur in May, 2013. Note, this is a consensus opinion, not a unanimous decision. A supermajority of the panel did agree to this prediction. [http://www.swpc.noaa.gov/SolarCycle/]
Effects of Solar Cycle on Remote Sensing Satellites

- path errors in GPS, radar altimetry, and InSAR
  - phase velocity > c
  - group velocity < c
  - error proportional to wavelength squared
    - Ku 23 mm - 0.1 m delay
    - C 56 mm - 0.8 m
    - L 150 mm - 5.0 m delay

- increased atmospheric drag on low orbiting satellites
  (e.g. GRACE - 400 km, GOCE - 250 km)

- risk to spacecraft health during solar maximum
  (South Atlantic anomaly)