VLF & ULF Signals, Receivers & Antennas

- *Listening to the sounds of the atmosphere*

A presentation to Manly-Warringah Radio Society

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VLF & ULF Signals, Receivers and Antennas

1. Signals

Spectrum of interest
- 300Hz to 3kHz (ULF)
- 3kHz to 15kHz (part VLF)
- There are Schumann resonances around 5-50Hz, but not as easy to receive.

Sounds to listen for
- Atmospherics
- Tweeks
- Whistlers
- Dawn Chorus

History of atmospheric "sounds"

- First noticed by early telegraphists, and then by rural telephone customers with long telephone lines (up to 22km long - copper was cheaper then!).
- Some studies done in early 20th century (Barkhausen, 1919).
- Became a serious subject for study post WW2.
- Storey (UK, 1953) showed they are caused by lightning strikes.
- Early reference text from Robert Helliwell (Stanford, 1965).

What sounds can you hear?

- Atmospherics ('spherics', or 'sferics')
- Tweeks
- Whistlers
- Dawn chorus
- See also McGreevy [5]

Atmospherics

- The sounds of nearby lightning strikes
- Approximately 100 strikes per second world-wide
- A typical cloud-to-ground stroke might be 10kA for 100µs!
- Listen to Attachment: ***spherics.au***

Tweeks

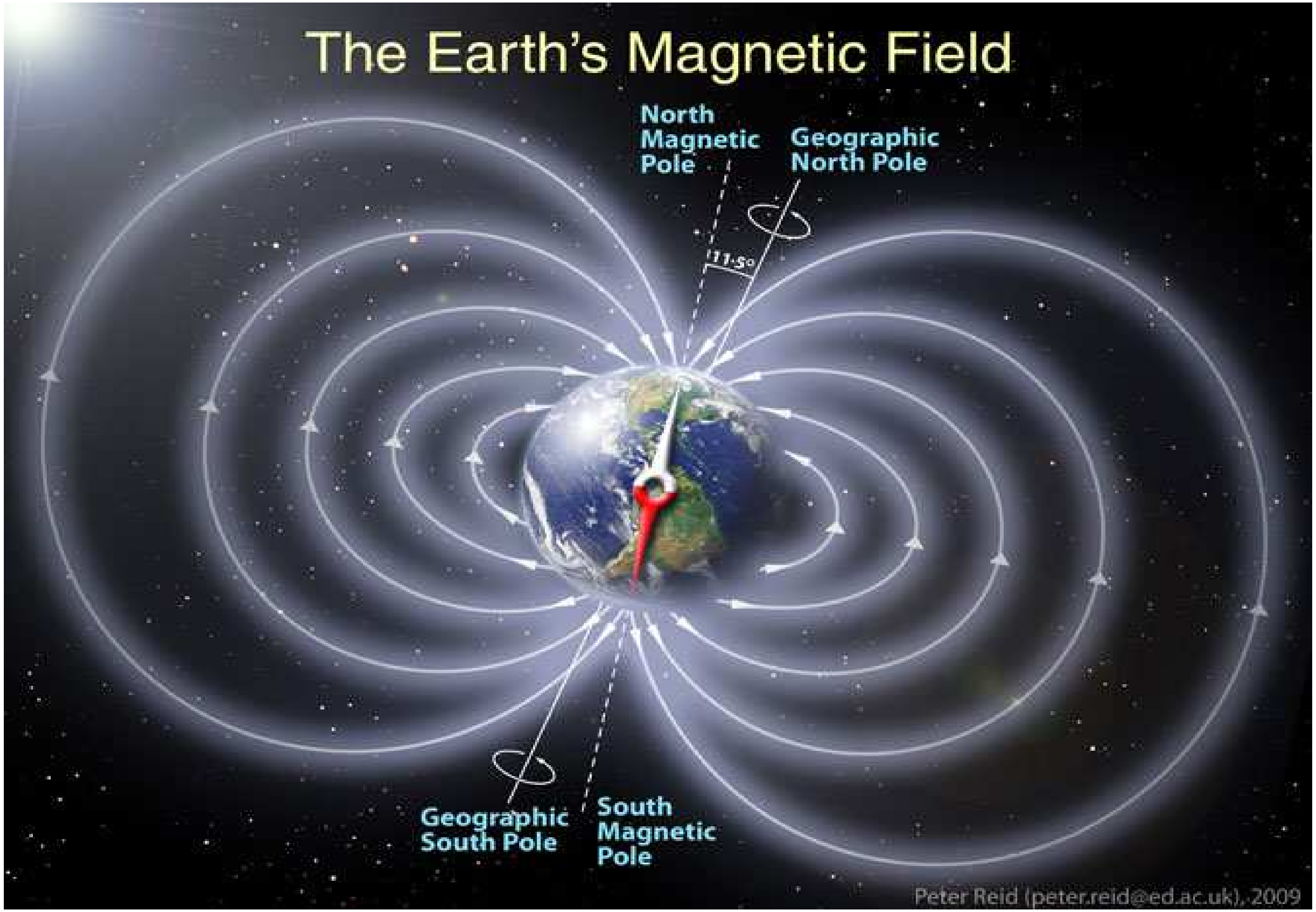
- At night when the Earth–ionosphere waveguide (slide 9) is highly conducting, the energy from an atmospheric travels with little attenuation and therefore many different ray paths can exist between the source and receiver.
- This causes group delay to increase and the effect is the arrival at the receiver of a train of pulses with a musical sound, called a "tweek".
  - Dispersion causes higher frequencies to arrive just before lower frequencies, hence the sharply descending notes.
- Listen to Attachment: ***tweeks.au***

Whistlers

- Energy from lightning near the earth's surface may travel along the Earth–ionosphere waveguide, but also enter the ionosphere and then travel along magnetic lines of force to re-enter the Earth–ionosphere waveguide in the opposite hemisphere.
- Whistlers are most evident at mid latitudes, peaking at about 50 degrees latitude. There is almost no activity at the equator and none at the poles.
- Whistlers generally originate from very powerful lightning strikes.
- Listen to Attachment: ***whistlers.au***

VLF & ULF Signals, Receivers and Antennas (cont'd)

Simplified diagram of Earth's magnetosphere, ignoring the solar wind.



VLF & ULF Signals, Receivers and Antennas (cont'd)

- The Earth–ionosphere waveguide occurs in the lower part of the ionosphere in the region between the Earth and the ionosphere.

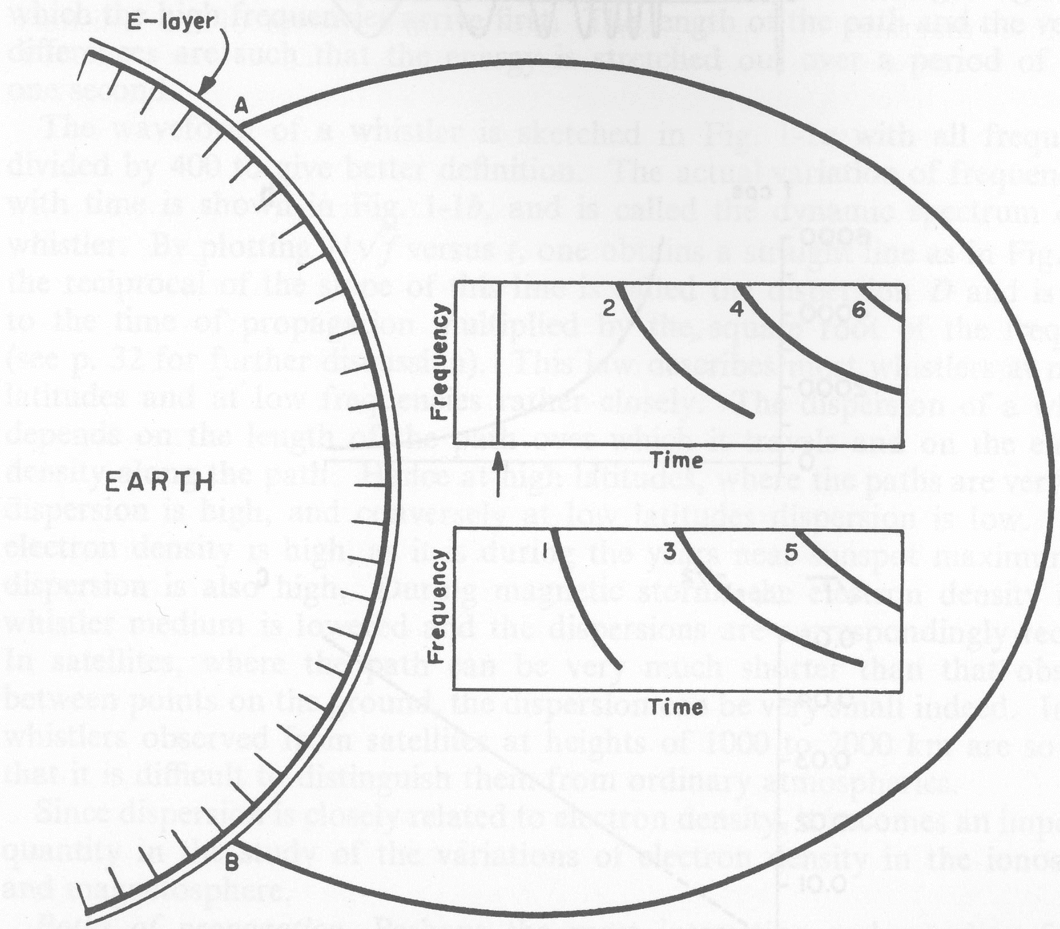


FIG. 1-2. Field-line path followed by a ducted whistler. Inset diagrams show idealized spectra of whistler echo trains at conjugate points A and B.

From
Helliwell (1965)

Dawn Chorus

- Occurs mostly around dawn.
- Believed to be generated by the interaction of high-energy electrons with VLF noise, injected into the Earth's magnetosphere.
- Occurs more frequently during magnetic storms
- Also occurs during aurorae and is then referred to as an auroral chorus.
- Listen to Attachment: ***chorus.au***

When to listen (See [5] and others)

- Over the long term, the period from two hours before sunrise until an hour after sunrise is the optimum time to listen for natural VLF phenomena of all sorts as the amount of spherics (lightning stroke pops and crackling) is lower.
- Statistically, the time between local midnight and an hour after sunrise is when the greatest number of whistlers are heard, although dusk to midnight may also have substantial activity.
- Tweeks are best heard after local sunset up to midnight.
- Listen to the dawn chorus 2 hours before sunrise, for a few hours, and during magnetic storm events.

2. Receivers [1, 2, 3]

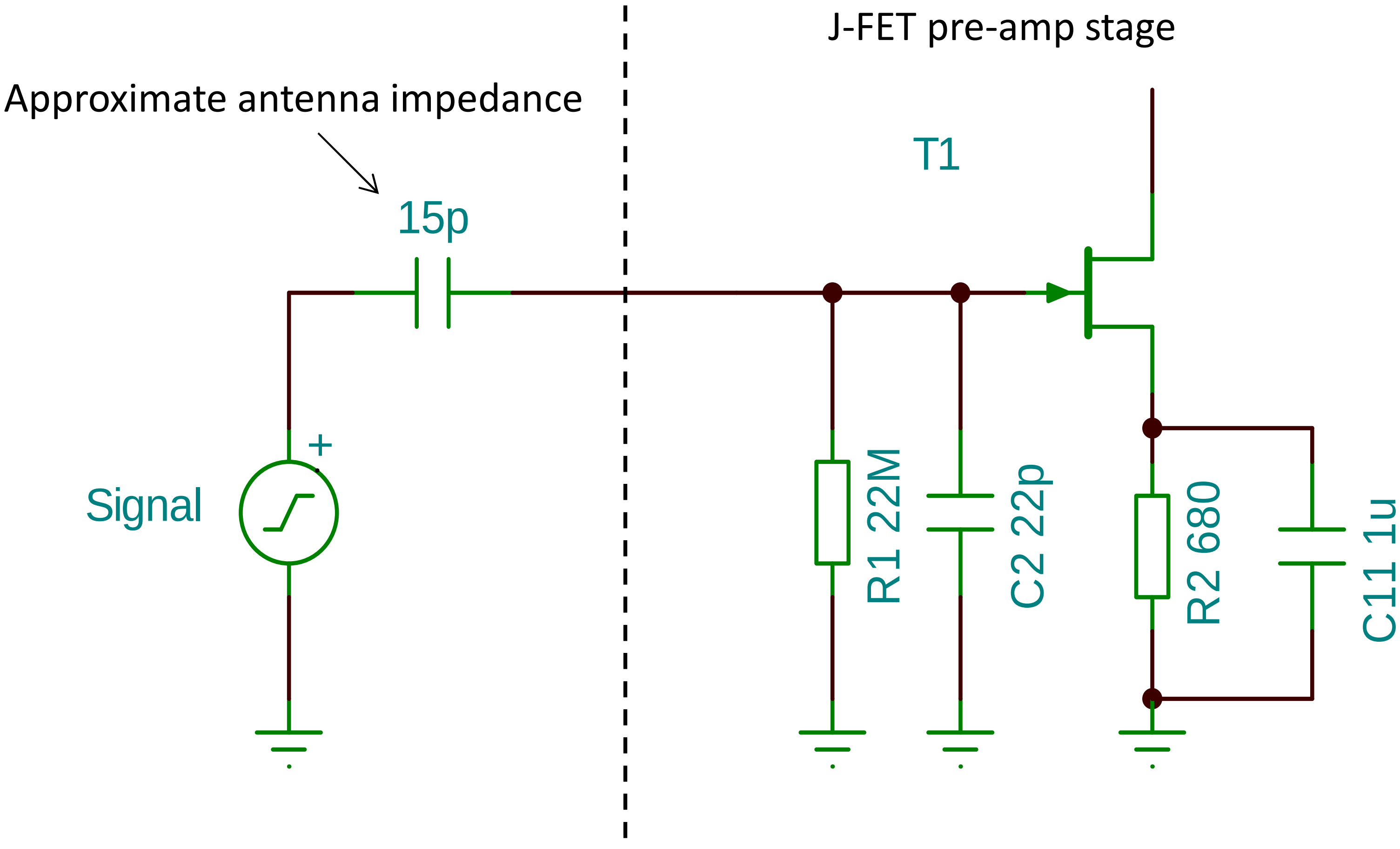
- Field strength ranges from about 5µV/m to 4mV/m [6]
- Basic receiver is an audio amplifier
  - With a 1m whip antenna, needs front-end gain of about 30dB to achieve a good SNR for recording purposes.
  - Ideal bandpass response from about 300Hz to 10kHz.
    - 50Hz interference is a big problem (audible).
    - Filter out broadcast station (overload & detection) – easy to achieve.
  - Can use filters in a purpose-designed receiver, get about 40dB attenuation at 50Hz and 20kHz, or …
  - Record signals and process on a PC with *Spectrum Lab*, *Spectran*, or similar DSP filter programs with "brick-wall" filters.
- Can use a simple (active) antenna impedance converter into a PC sound-card input, then DSP as above.
  - May get overload from broadcast stations without a LPF …!

3. Antennas

- Simplest antenna is a short 1m vertical whip (E-field).
  - A 1m vertical whip looks like a 15pF (approx) capacitor between the signal and the input of the amplifier. Therefore the input impedance of the amplifier needs to be about 22 Megohm (or more) to lower the high-pass filter corner-frequency and reduce LF attenuation.
- To receive lower frequencies (down to 10Hz), a 10-15m long wire can be used in place of the whip. Increases SNR.
- Magnetic loop (B-field) antenna is balanced and can eliminate some interference, but requires a more complex pre-amplifier.

Caution - always be careful when there is electrical storm activity about *!!*

Typical input circuit with 1m vertical whip antenna



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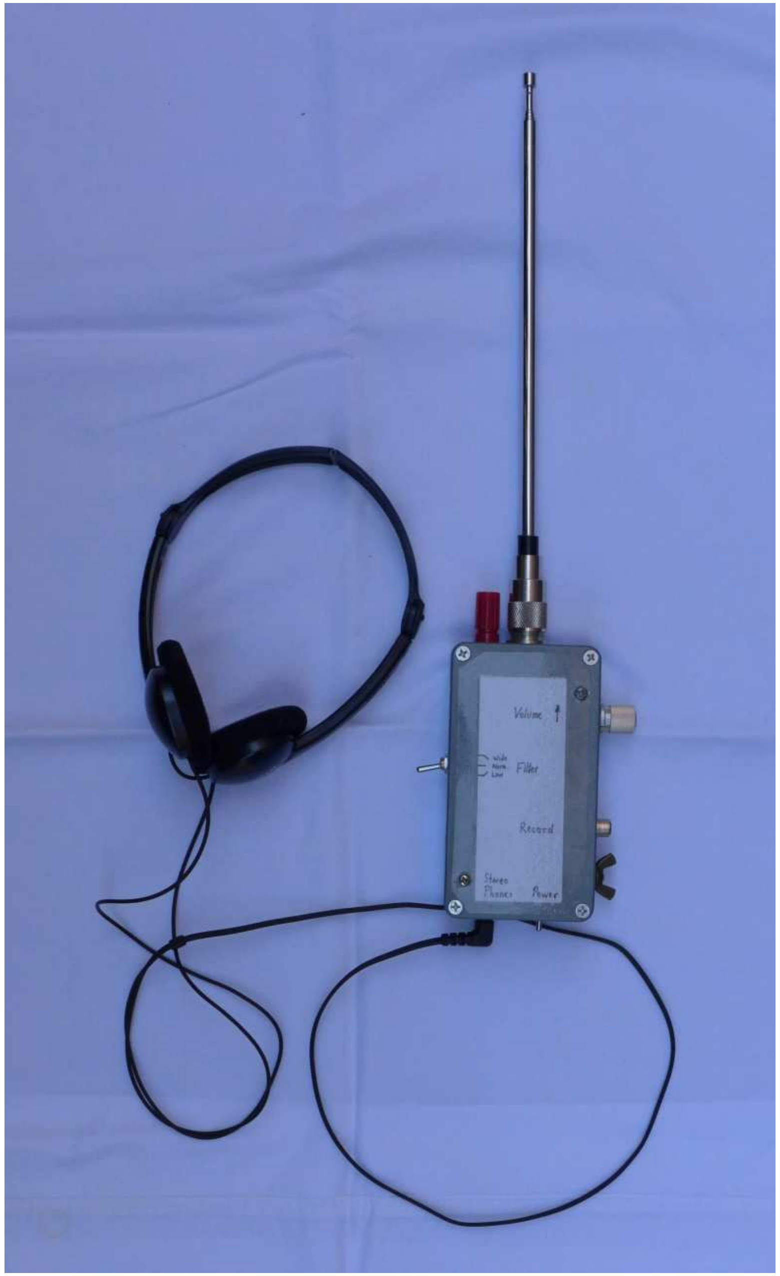

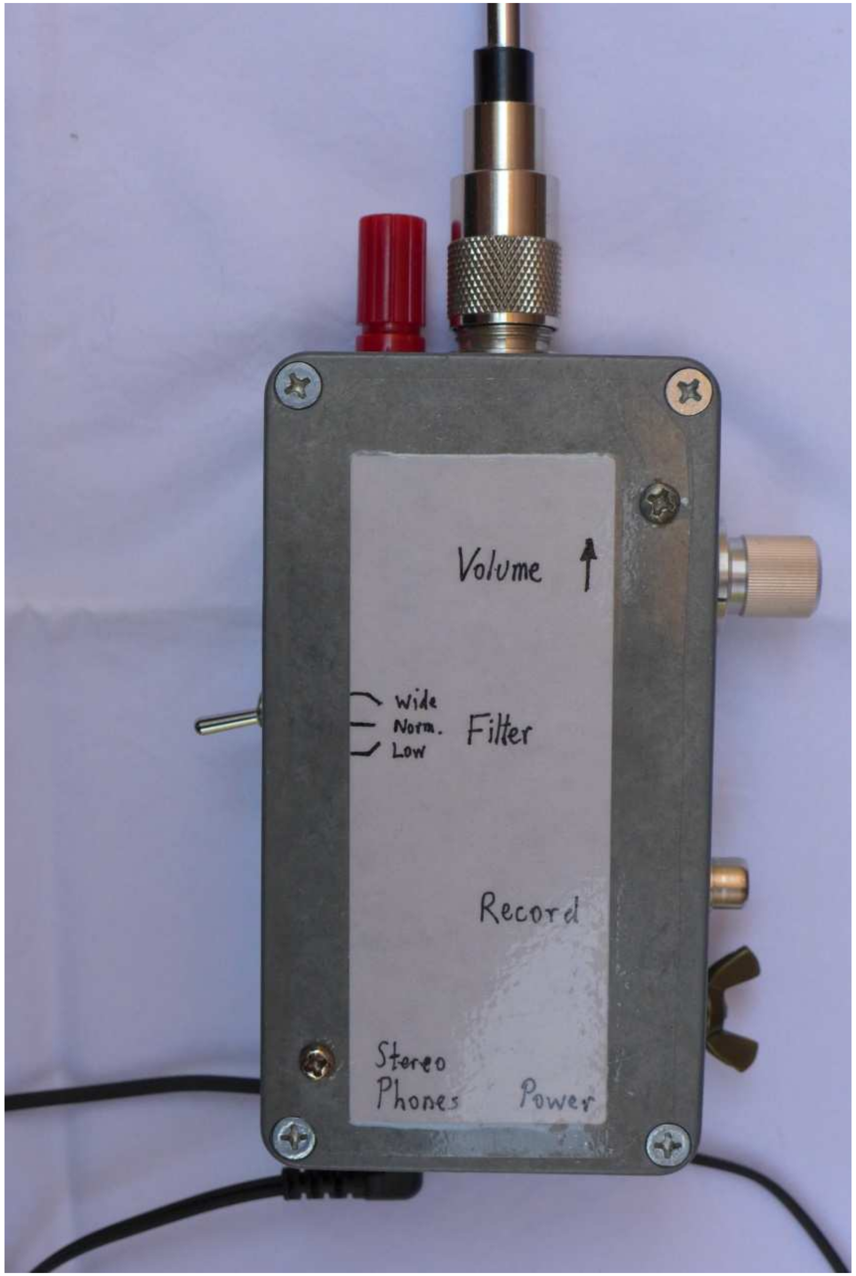

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