630-Meter and 2200-Meter Propagation

CARL LUETZELSCHWAB K9LA

ARRL CENTRAL DIVISION VICE DIRECTOR

E-MAIL: K9LA@ARRL.NET

PROPAGATION WEB SITE: HTTPS://K9LA.US

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Our Two New Bands

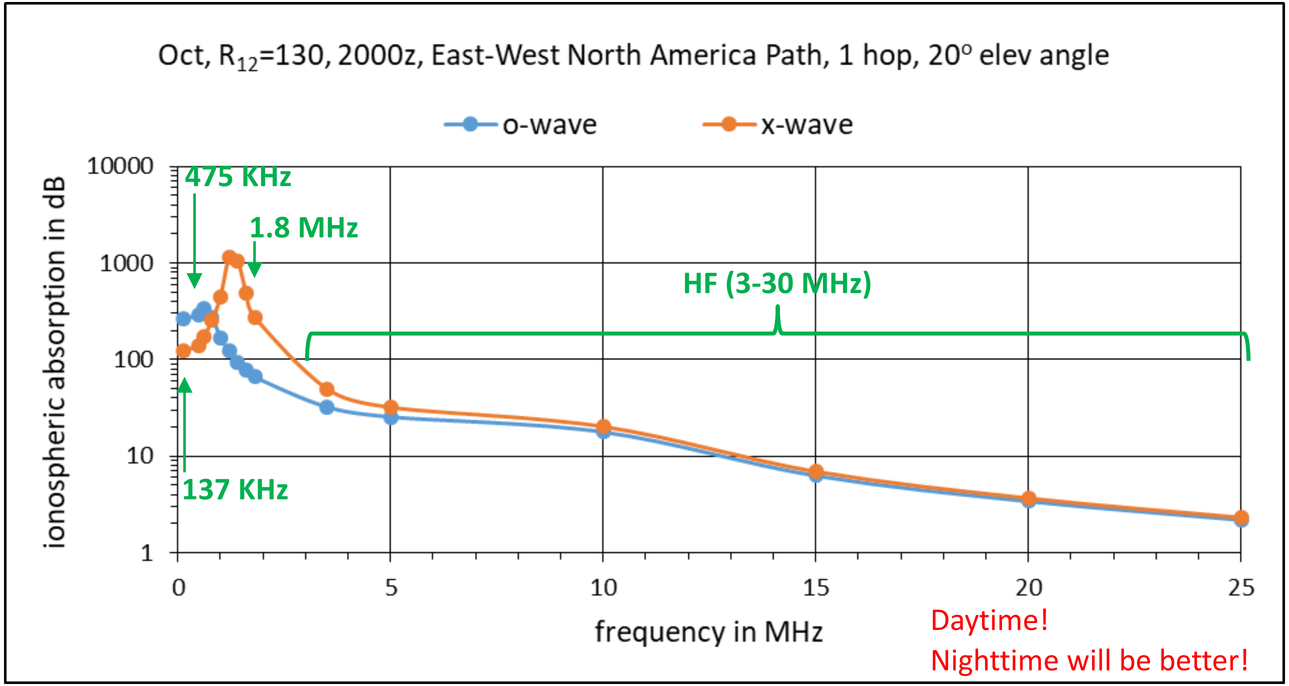
- They became available for everyone to use in 2017
- 630m is 472-479 KHz (7 KHz wide)
  - 5 W EIRP max (except in KL7 within 496 miles of Russia – 1 W)
- 2200m is 135.7-137.8 KHz (2.1 KHz wide)
  - 1 W EIRP max
- Must fill out a form giving your latitude/longitude to Utilities Technology Council and wait for their response
  - Can't be within 1 km of PLC (Power Line Carrier) systems
- The big question – is Topband still the top band?

The Big Picture

- How do ionospheric absorption, refraction and polarization vary versus frequency?
- These three items determine if a QSO is successful
  - Ionospheric absorption – too much absorption puts the signal below the noise threshold of the mode you're using
  - Refraction – if not enough, signal doesn't return to Earth
  - Polarization – there can be a mismatch loss between your antenna and the ionosphere
    - There's more order to polarization than many people realize because the ionosphere is immersed in a magnetic field

Ionospheric Absorption versus Frequency

- At HF, o-wave and x-wave incur about the same amount of absorption
- At 1.8 MHz, the o-wave incurs the least absorption
- At 475KHz and 137 KHz, the x-wave incurs the least absorption *for the path evaluated* (more on this later)

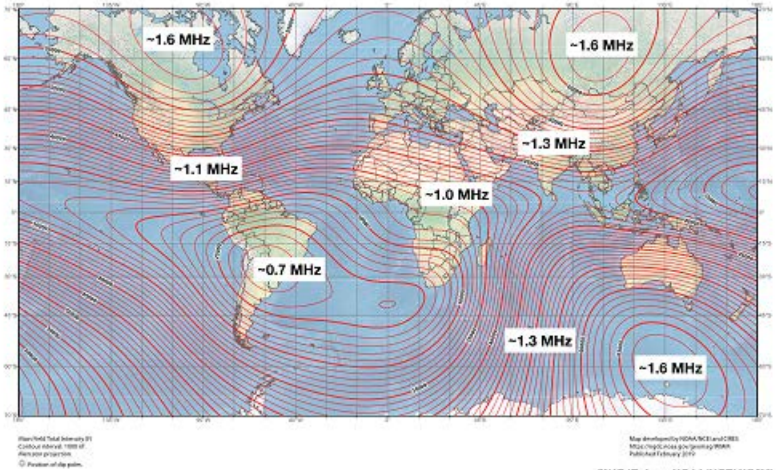


Proplab Pro V3, Appleton/Hartree (mag field), IRI 2007, electron-neutral collisions

The Cause of Unequal Absorption

- The electron gyro-frequency is the cause
- Varies worldwide from 0.7 (South Atlantic Anomaly) to 1.6 MHz
  - About 20% lower at F2 region altitudes
- Impacts absorption thru equation 7.25 in Ionospheric Radio (Davies, 1990)

Estimated Electron Gyrofrequency (MHz)
From US/UK World Magnetic Model (WMM)
Year 2019



[W1PJE; from NOAA/NCEI WMM]

$$\frac{\text{electron density times collision frequency}}{(\text{op freq} \pm \text{longitudinal component of gyro-freq})^2 + (\text{collision freq})^2}$$

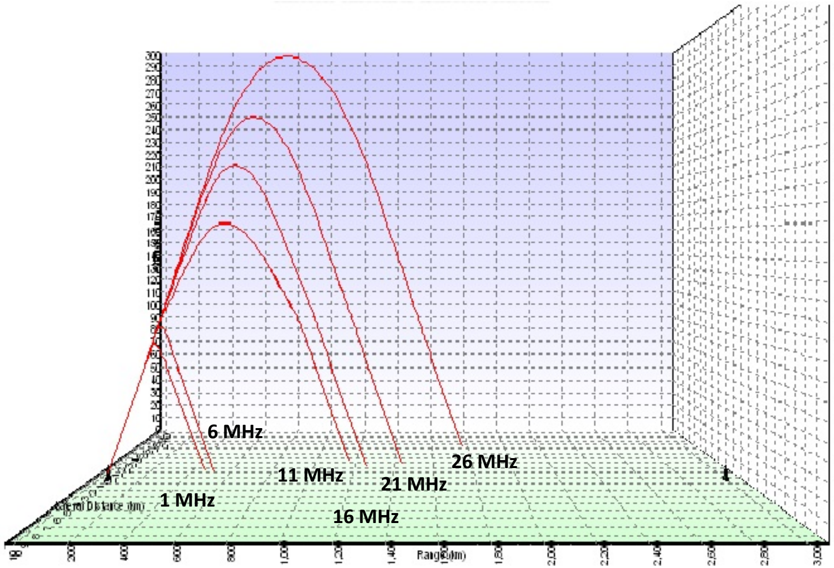
integrate this eqn over height

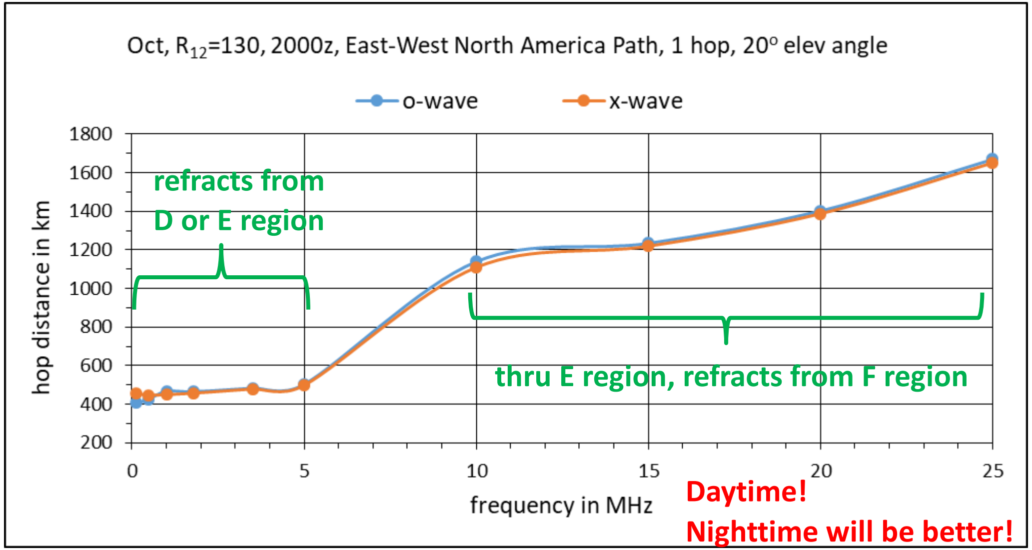
(+ is ord, - is extraord)

= gyro-freq times cos Θ (angle between RF and mag field)

Refraction versus Frequency

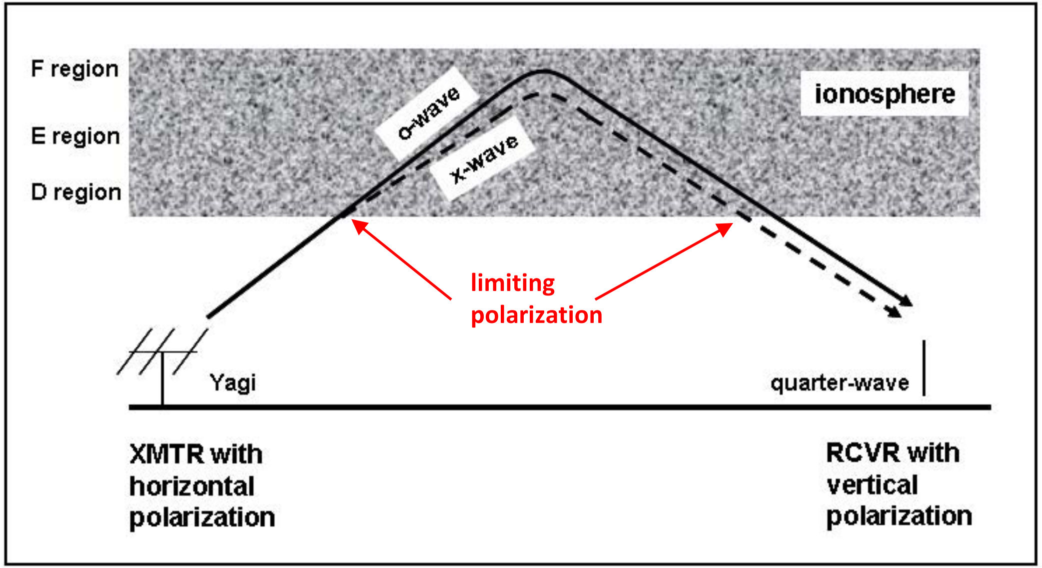
- The ray traces also give hop distance versus frequency
- The lower the frequency, the shorter the hop
- Between 5 and 10 MHz is a transition region – from F_2 hops to E or even D hops





What Happens to Our RF When We Transmit?

- It couples into the two characteristic waves that can propagate differently through the ionosphere – the ordinary wave (o-wave) and the extraordinary wave (x-wave)
- How much energy couples into each characteristic wave depends on our antenna polarization and the polarization of the two characteristic waves at the entry point of the ionosphere



This is what is important – the 'limiting' polarization – our transmit antenna should be of the same polarization as the dominant characteristic wave

Polarization Can Vary

from The Magneto-Ionic Theory & Its Application to the Ionosphere (Ratcliffe, 1962)

- $w_c = w_H \times \sin^2\Theta/(2 \times \cos\Theta)$
  - w_H is angular gyro-frequency
  - Θ = angle between RF direction and magnetic field
    - this is a 3D angle !!!
- v is collision frequency
- w is angular operating frequency
- X = (angular plasma freq)^2/(angular operating freq)^2
- Vertical axis
  - w_c/v = 0.1 is ~ longitudinal propagation (parallel)
  - w_c/v = 5.0 is ~ transverse propagation (perpendicular)
- Horizontal axis - when does ξ approach 0?
  - When X = 1 (plasma freq equals op freq)
  - When w is small and w_c is large
  - These indicate transverse prop on low frequencies

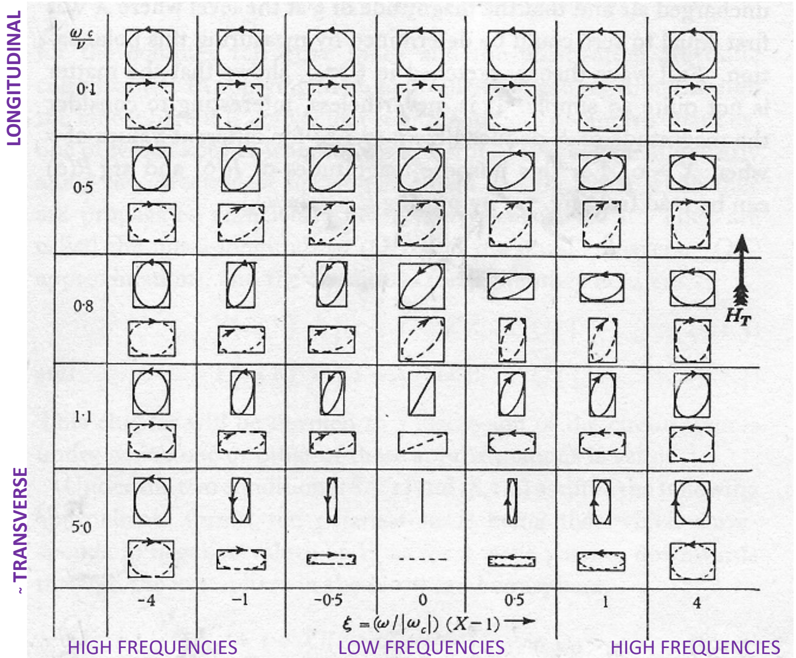


Fig. 7.6. Sketches of the electric-field polarisation ellipses corresponding to some given values of $|\omega_c/\nu|$ and ξ. The positive wave-normal direction and the longitudinal component of the imposed magnetic field are directed into the paper. The projection of the imposed magnetic field is shown labelled H_T. With negatively charged electrons the continuous line represents the Ordinary wave and the dashed line the Extraordinary.

Polarization on Our New Bands

- Many, many more 475 KHz/137 KHz ray traces for day/night, different elevation angles and solar min/solar max show that either the ordinary wave or the extraordinary wave could be best (in terms of least absorption) under different conditions
- From Ratcliffe's figure, each characteristic wave could be circular to elliptical to linear
- This suggests an antenna with both vertical and horizontal polarization should be best

So Far . . . .

- Ionospheric absorption is more on our new bands
- Hop distance is shorter on our new bands
- Polarization is important on our new bands

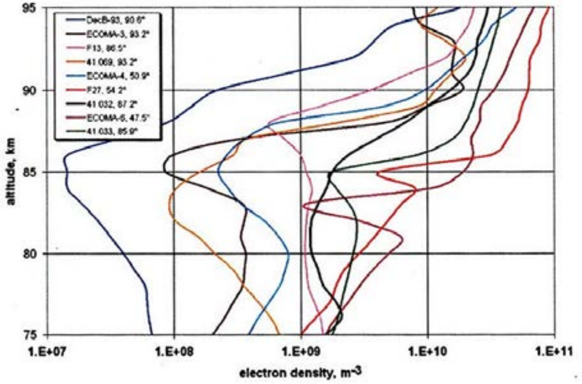
This gives us shorter and more lossy hops

More Comments from the Ray Traces

- Propagation on 630m and 2200m is different
  - 2200m not likely to get through the E region – even at night
- Sky-wave propagation during the day on both bands is limited in distance
  - Nighttime is the best on both bands (as is on 160m)
- Absorption may be decreased in D region bite-outs (next slide)
- Ducting at night may be possible on both 630m and 2200m
  - On 630m – in the electron density valley
  - On 2200m – in the D region bite-outs – speculation!
- Negative ions at night may help signal level on both bands
  - An electron can attach to a neutral constituent at D region altitudes to become a heavy negative ion which does not participate in the absorption process
  - Electron affinity can be low enough for UV to detach them before sunrise

Even More Comments

- D region may not be a monotonic decrease vs decreasing altitude



Could these bite-outs help?

- Antennas are inefficient – especially on 2200m – and it's tough to generate low angle radiation at these low frequencies
- Man-made noise on both bands could be a problem
- Ground wave propagation can be a big factor on 2200m
  - Out to ~ 900 km per ITU ground wave curves over average ground when decoding by ear

What About the Real World?

- Up until now, everything has been theoretical
  - Assumed ray tracing is correct and relied on accuracy of IRI 2007
- Experimental work on 630m prior to 2017
  - WG2XIQ (TX) heard by VK2DDI on WSPR on Aug 25, 2014 (all dark path)
  - W5EST measured WG2XXM (433 km) on Sep 22, 2014 – saw SNR decrease prior to sunrise – electrons detaching from negative ions?
- Swedish SWL monitored 354-434 KHz
  - Heard 387 KHz 20W Spanish station – 2000 km
  - Saw “after dawn” boost on signals parallel to the terminator
- Bob NZ5A monitored 200-500 KHz (LF/MF) for three years
  - His article should be in the August QST – mostly applicable to 630m
  - Around sunrise and sunset during October were most productive for him

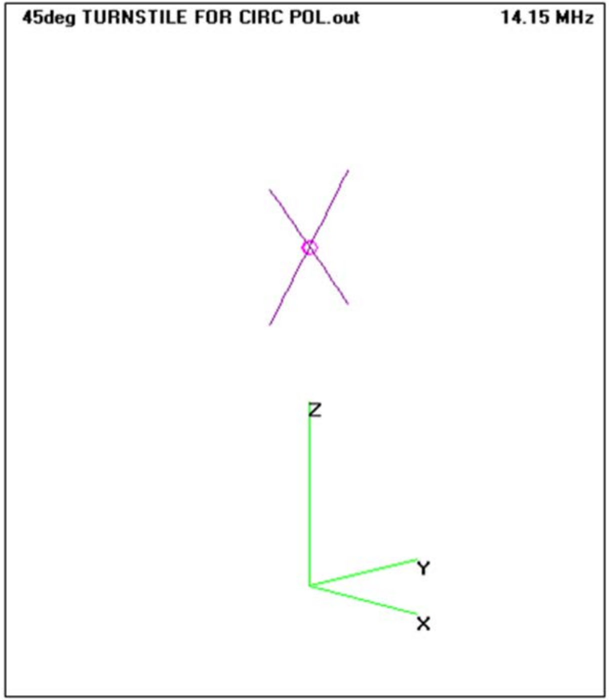
Summary

- CW is viable, but go digital to gain SNR advantage
- Polarization diversity is key
  - Put up an antenna with both vertical and horizontal polarization – for example, an inverted-L
- We have a lot to learn
- Document your efforts
- Report to the world (or at least to HamSCI !)

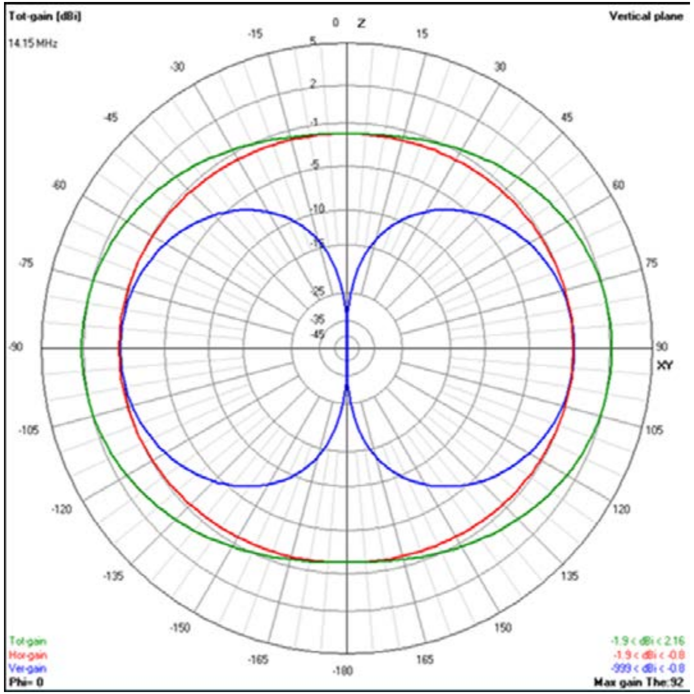
visit https://k9la.us/Dec18_Propagation_on_630m_and_2200m_-_revised_24Dec2018.pdf
for more details of this presentation

Generating Circular Polarization at HF

- Helix, twisted elements on boom, turnstile
- Turnstile may be the easiest at HF
- Vertical gain and horizontal gain are equal on the nose in free space
- Total gain in free space is 3 dB more than either horizontal or vertical
- In the 1960s, *Space-Raider* (original K6CT) made cir-pol Yagis for 20m, 15m, 10m and 6m using turnstile elements



20m crossed-dipole array at 60 feet



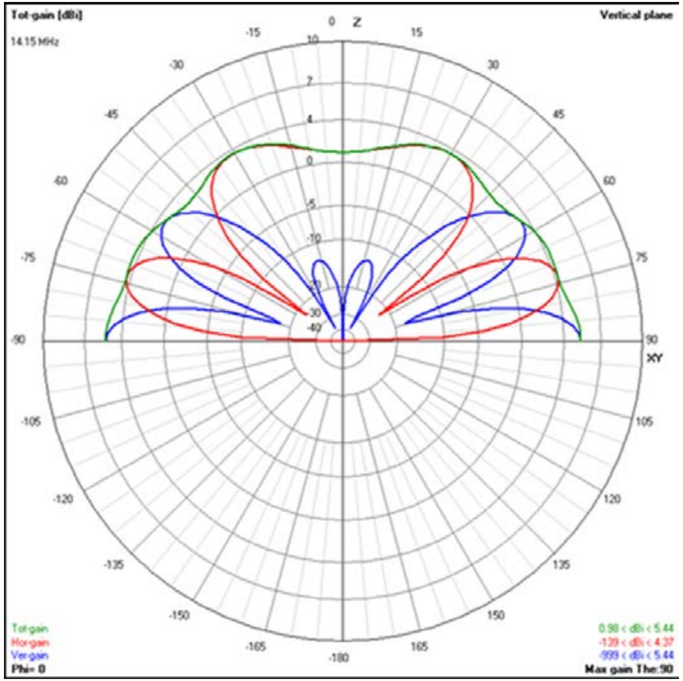
elevation pattern in free space

red is horizontal gain

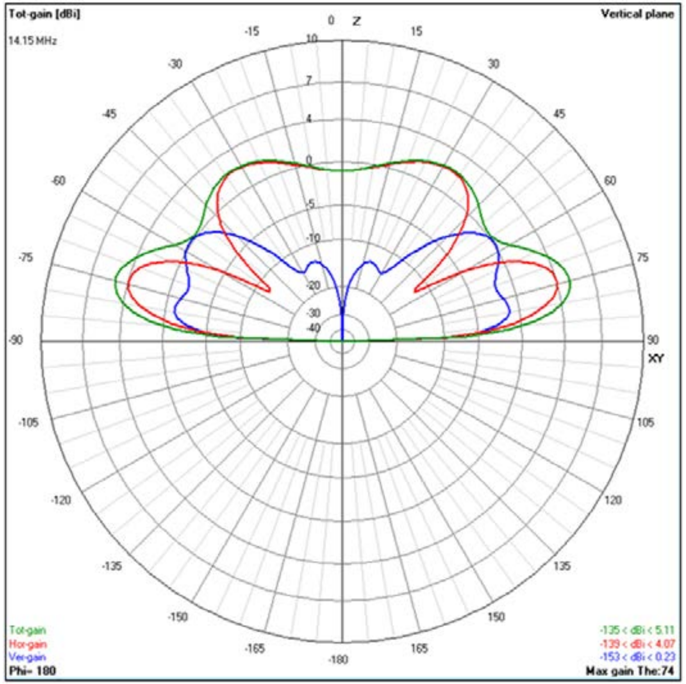
blue is vertical gain

Turnstile Over Two Different Ground Conditions

- Not perfect cir-pol in either case
- Over avg gnd, kind of cir-pol at lower elevation angles
- Over both gnd conditions, no nulls in elevation pattern
- Is cir-pol worth the effort on HF?



over perfect gnd at 60 feet



over avg gnd at 60 feet