Principals of Radio Frequency Propagation "DC to Light"

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by

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Amateur Radio: Novice 12-7-54, Advance 4-56 General, 5-56, extra, 7-65, 20 wpm

TABLE OF CONTENTS

Page 1	In the beginning
Page 2	Fundamental equations
Page 3	Propagation Modes
Page 4	The sun's effects
Page 5	Ham Bands vs propagation
Page 6	References

Figure 1	Ionosphere Structure
Figure 2	Regions of lower atmosphere and ionosphere
Figure 3	Typical "skip profile"
Figure 4	Multi-hop skip
Figure 5	Back-scatter
Figure 6	Gray-line
Figure 7	Trans-equatorial TE mode

IN THE BEGINNING

Albert Einstein, e = mc (1905)

God created light. Then Ham Radio follows in 4.543 billion years!

- All starts when Newton discovers gravity
  F = MA Newton's Second Law (1687)
- Faraday, Coulomb, other forces(1700 -1850s)
- Maxwell Equations tie forces together (1868)
- Hertz proves radiation exists and confirms speed of light, 300 million meters/sec (1887)
- Tesla one way transmission. The boat (1902)
  The patent wars begin who discovered radio
- Marconi (1st Ham) invents first 2 way radio "spark" communications system. (1904)
- Titanic sinks. Ham radio is born (1912)
- ARRL Founded (1914)
- First AM Station KDKA goes on the air (1920)
- Wall Street Crash, Ham radios grows (1929)
- FCC born. Hams begin to loose bands (1934)

FUNDAMENTAL EQUATIONS

- Hertz $\lambda = c/f$
- Maxwell (1) divD = P
  (2) divB = 0
  (3) curlE = - dB/dt
  (4) curlH = dD/dT + J
- Inverse Square Laws, Coulomb, Newton
  $s/4\pi r = 1$ ie, when the distance doubles the signal reduces by ¼, ie. -6db
- Free Space Path Loss Equations (FSPL)
  $FSPL = (4\pi Df/C)^2$
  FSPL = 32.4 + 20logD + 20logF (in db)
  $Pr/Pi = D_1 D_2 (\lambda/4\pi d)^2$

PROPAGATION MODES

- Ground wave, Tesla power grid
- Sky wave
- Conduction, earth, sea
- Reflection, Ionosphere layers, D, E, F, skip, radar, moon-bounce, metals in flight
- Refraction, Snell's Law, knife edge diffraction
- Multi-hop, multi-mode
- Waveguide, metal pipe, ion cloud - ion cloud
- Ducting, thermal inversion
- Polarization, vertical, horizontal, circular
- Faraday Rotation, V to H to V to H
- Line of Sight (LOS)   We see the stars
- Scatter, tropo, back, forward, volume
- Sporadic E, The magic band, 6 meters
- Aurora Borealis, occurs at both poles daily
- Gray Line, solar eclipse, shadows in action
- Trans-equatorial, north-south prop daily
- Meteor Showers, ionized trails, lightning
- Mirages, hot, cold examples desert, sea
- Artificial, HARP, Satellite, Internet

THE SUN'S EFFECT ON ALL PROPAGATION

- NO SUN NO ANYTHING! WE ARE NOT HERE!
- 27 DAY CYCLE-One day on the sun
- 11 Year Sun Spot Cycle, now in cycle 25 #
- Quite sun, minimum or no spots
- Active sun, solar flares, mass ejections, coronal holes (cool spot), radio black outs, lots of spots generally means 20 to 6 meters are open for DX
- Night time sun, ionosphere cools, MUF goes down
- Day time sun, ionosphere heats up, MUF goes up.
- The Gray line sun, daily occurrence 12/24 cycle, 20 to 30db enhancement Best on 160, 80 meters

Cycles since astronomer Rudolph Wolf recorded and started counting them 1847

HAM RADIO BANDS VERSUS PROPOGATION

	Ham Bands	Principal Mode(s)
• VLF	450 Khz and below	*groundwave
• MW	0.45 to1.8 Mhz (160 meters)	skywave
• HF	2-50 Mhz (80-6 m)	skywave, # E skip
• VHF	2 meters, 220Mhz	+LOS, duct, tropo
• UHF	440 Mhz, 902 Mhz	LOS, duct, tropo
• micro	1.2 Ghz and up, L, C, X	duct, LOS
• SHF	15 Ghz and up, Ku, mm, 4/5G	duct, LOS
• Light	infra-red to ultra-violet	LOS
• Rays	X, gamma, high energy particles	LOS

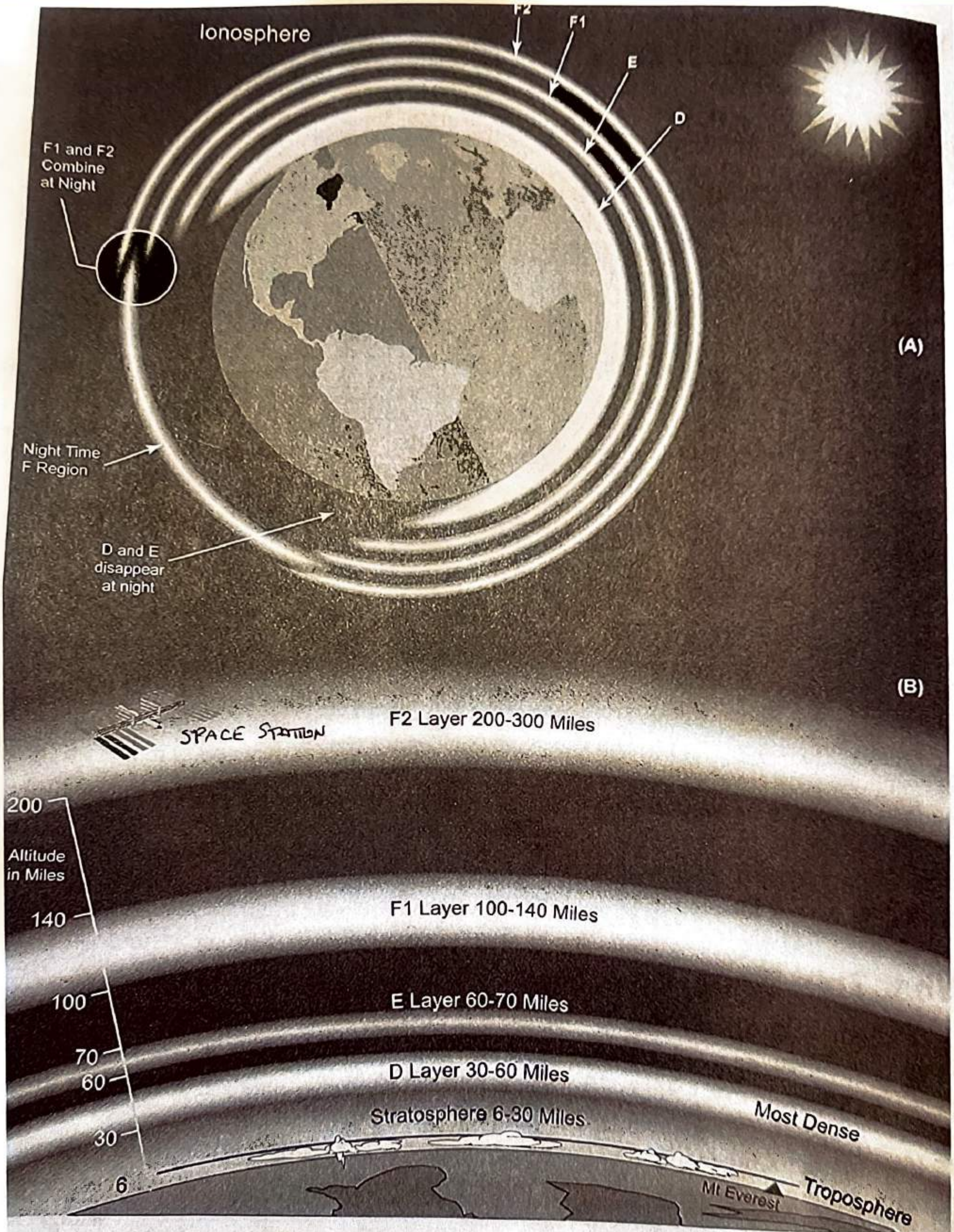
conduction via earth and sea water
secondary modes

6 meter E skip, regular, occurs seasonally

+ F skip very rare on 2 meters but does occur

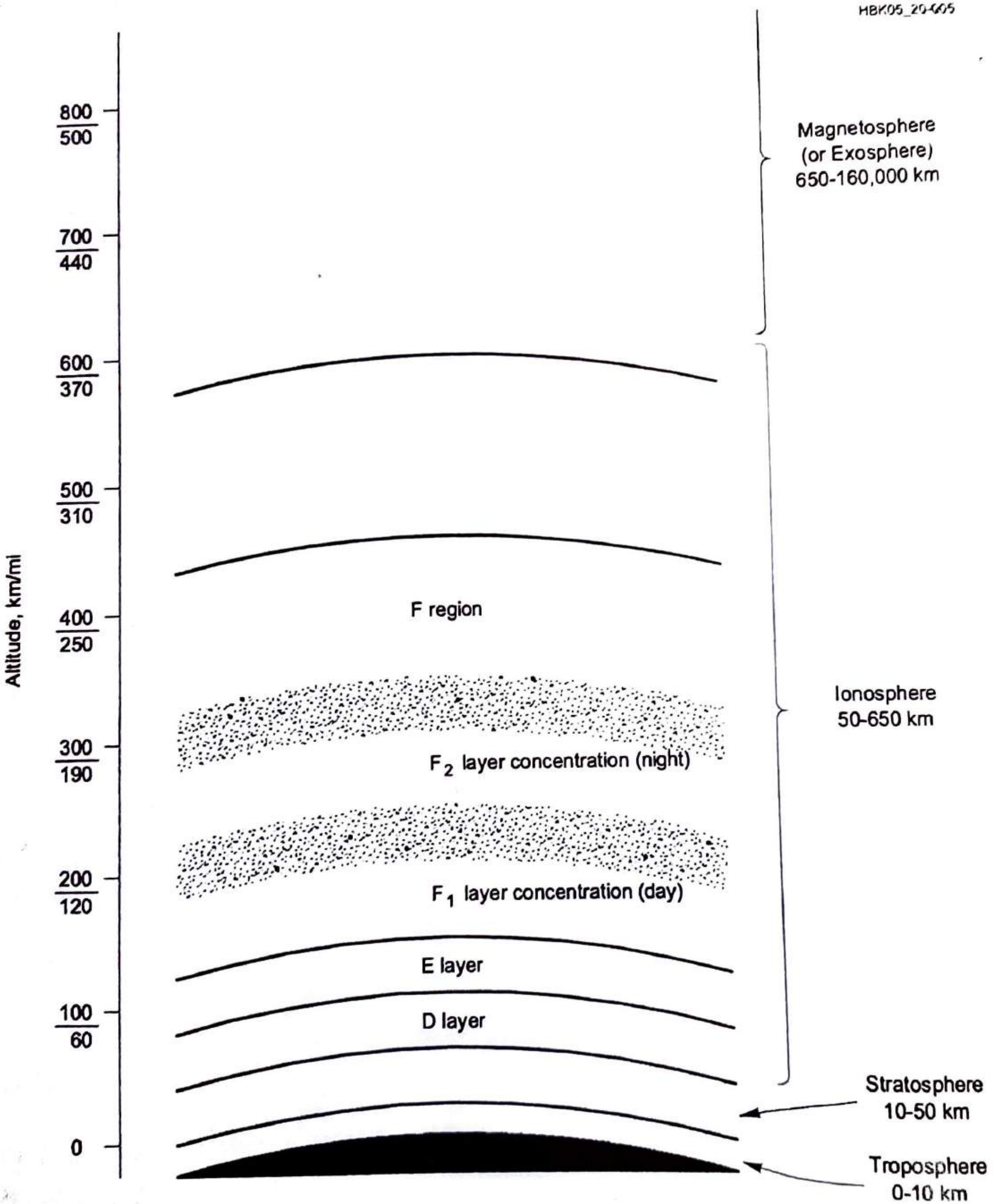
References:

- ARRL pubs — "From here to There" 1st edition, Cycle 25
- "Electromagnetic Spectrum Chart" available on internet free
- "Atomic Periodic Table" available on internet free



—The Ionosphere consists of several regions of ionized particles at different heights above the . At night, the D and E regions disappear and the F1 and F2 regions combine to form a single F region.

FIGURE 1



gure 2 — Regions of the lower atmosphere and the Ionosphere.

FIGURE 2

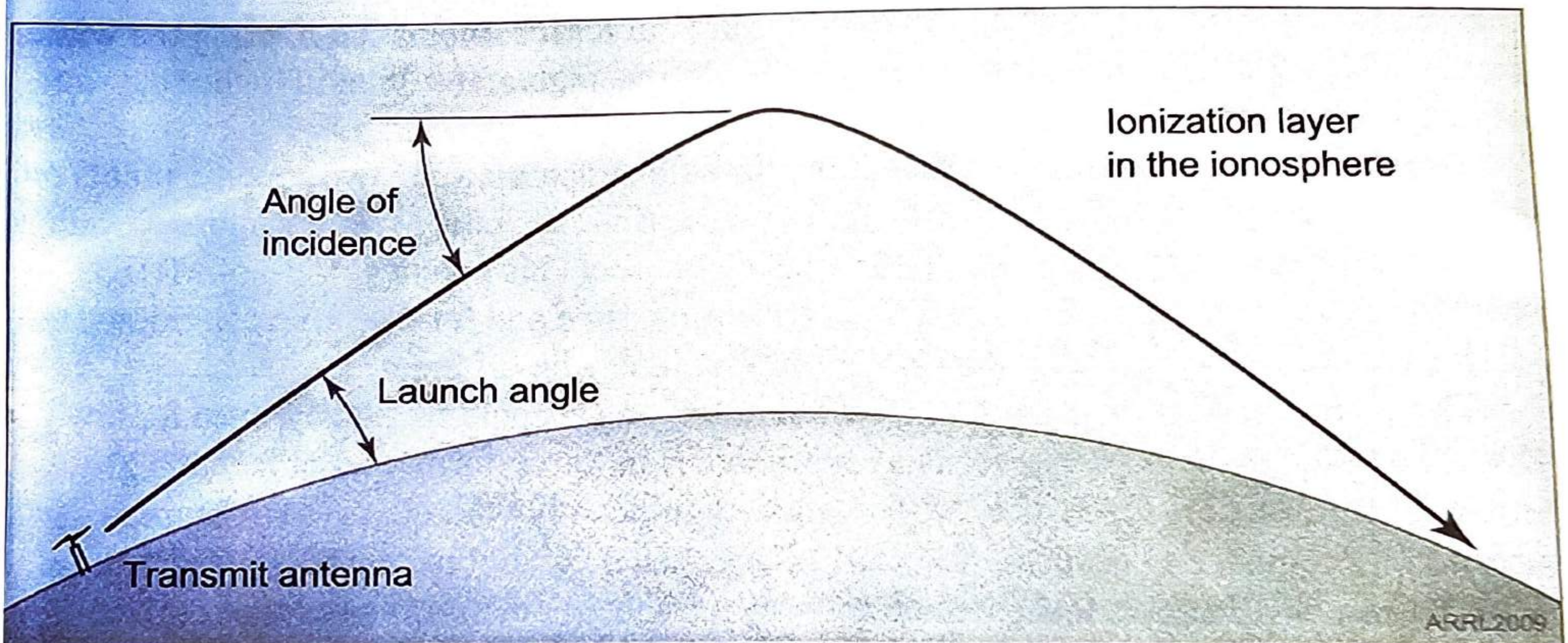


Figure 3 — A wave's launch angle at the transmitting antenna is not the angle of incidence for the wave at the onosphere because of the spherical nature of the Earth-Ionosphere geometry.

FIGURE 3

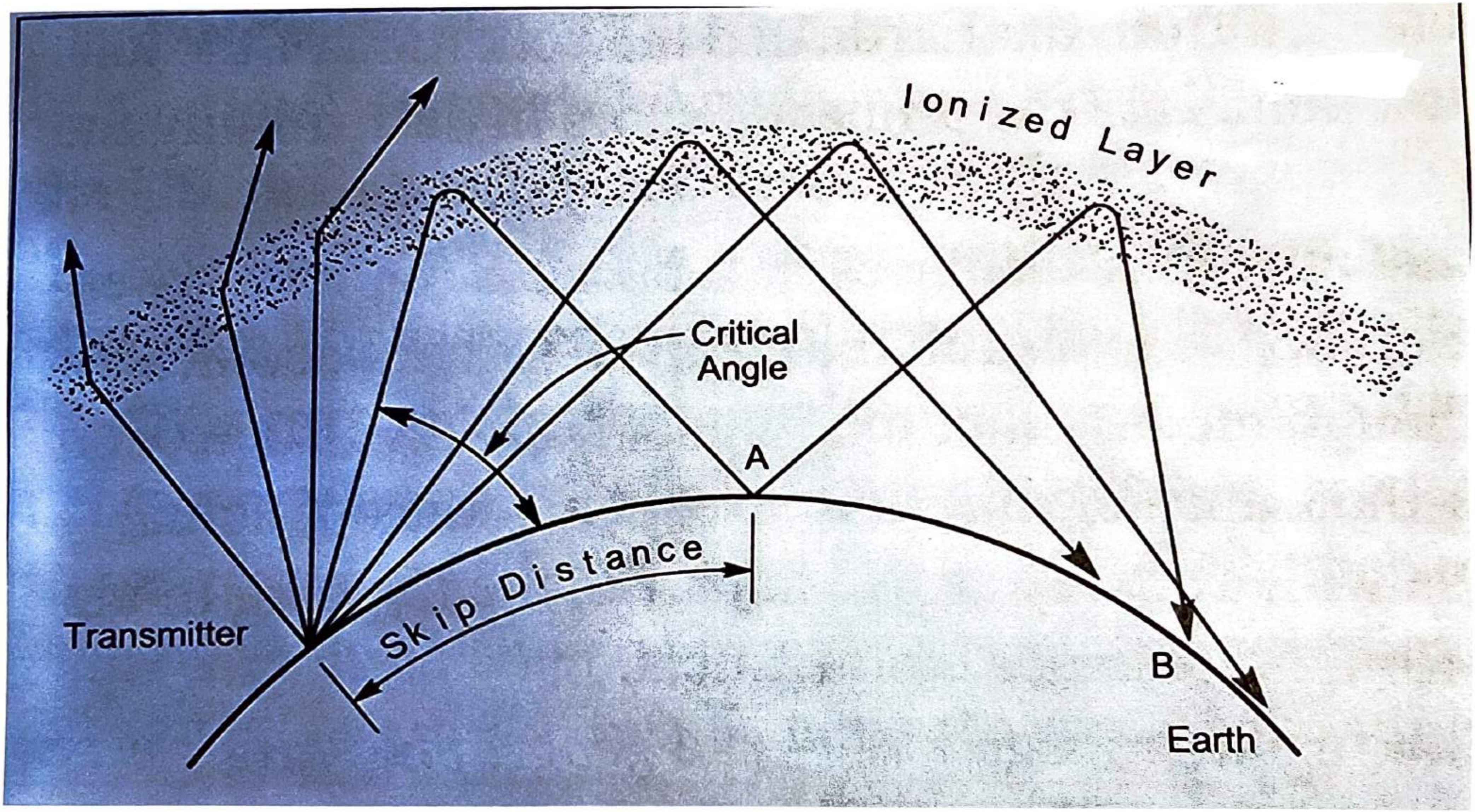

Ionized Layer
Critical Angle
A
Transmitter
Skip Distance
B
Earth

FIGURE 4

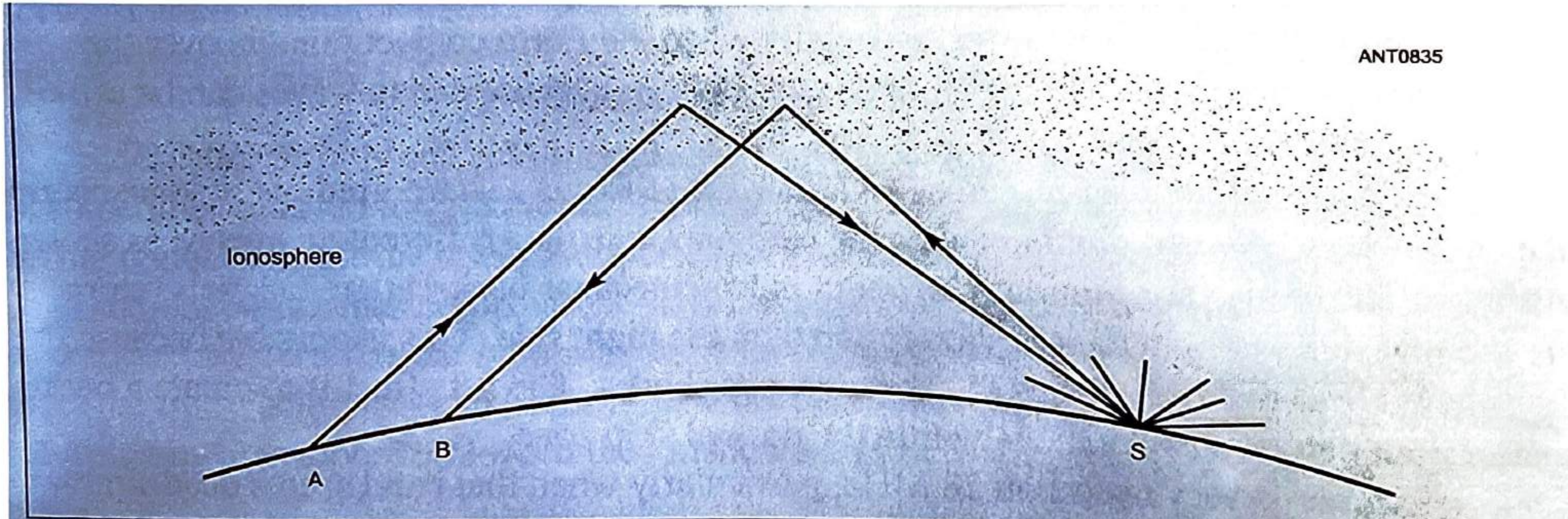


Figure 5 — Schematic of a simple backscatter path. Stations A and B are too close to make contact via normal F-region ionospheric refraction. Signals scattered back from a distant point on the Earth's surface (S), often the ocean, may be accessible to both A and B to create a backscatter circuit.

FIGURE 5

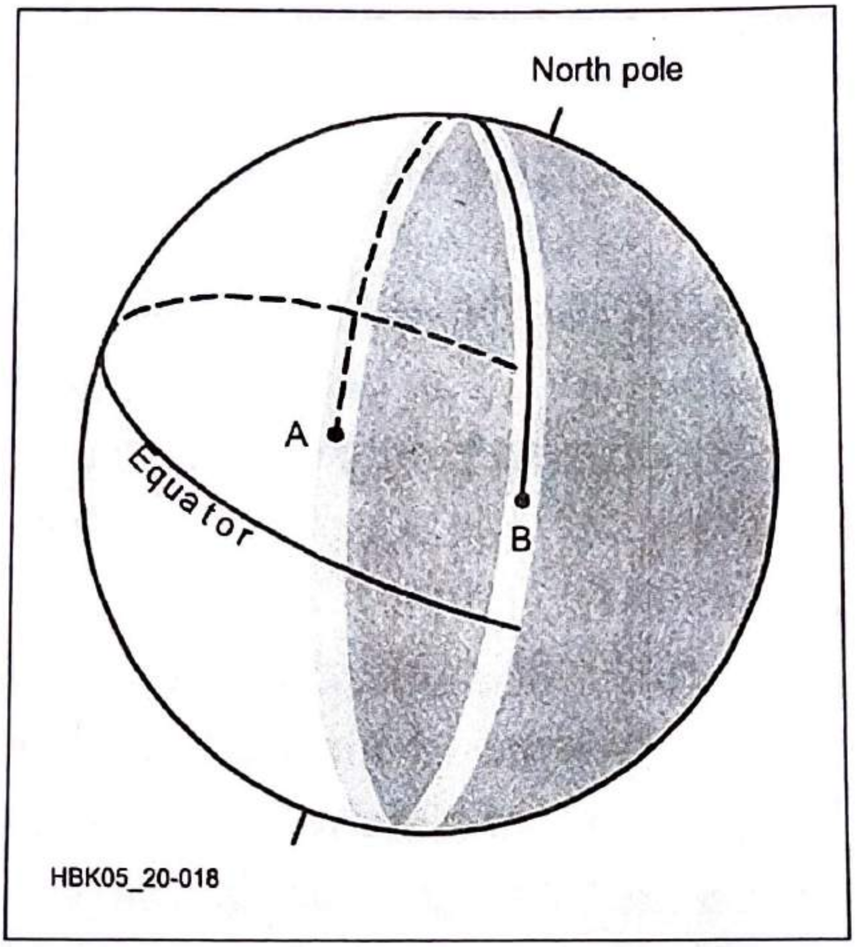


Figure 41 — The grayline encircles the Earth, but the tilt at the equator to the poles varies over 46 degrees with the seasons. Long-distance contacts on 1.8 MHz and 3.5 MHz at more than halfway around the Earth can be enabled by the grayline, putting both ends of the path near darkness and allowing RF to cut across the dark ionosphere with minimal absorption. The strength of the signals indicates that multiple Earth-ionosphere hops are not the likely mode of propagation, since losses in many such hops would be prohibitive. Ducting in the electron density valley above the E-region peak in the dark ionosphere is the likely mechanism.

FIGURE 6

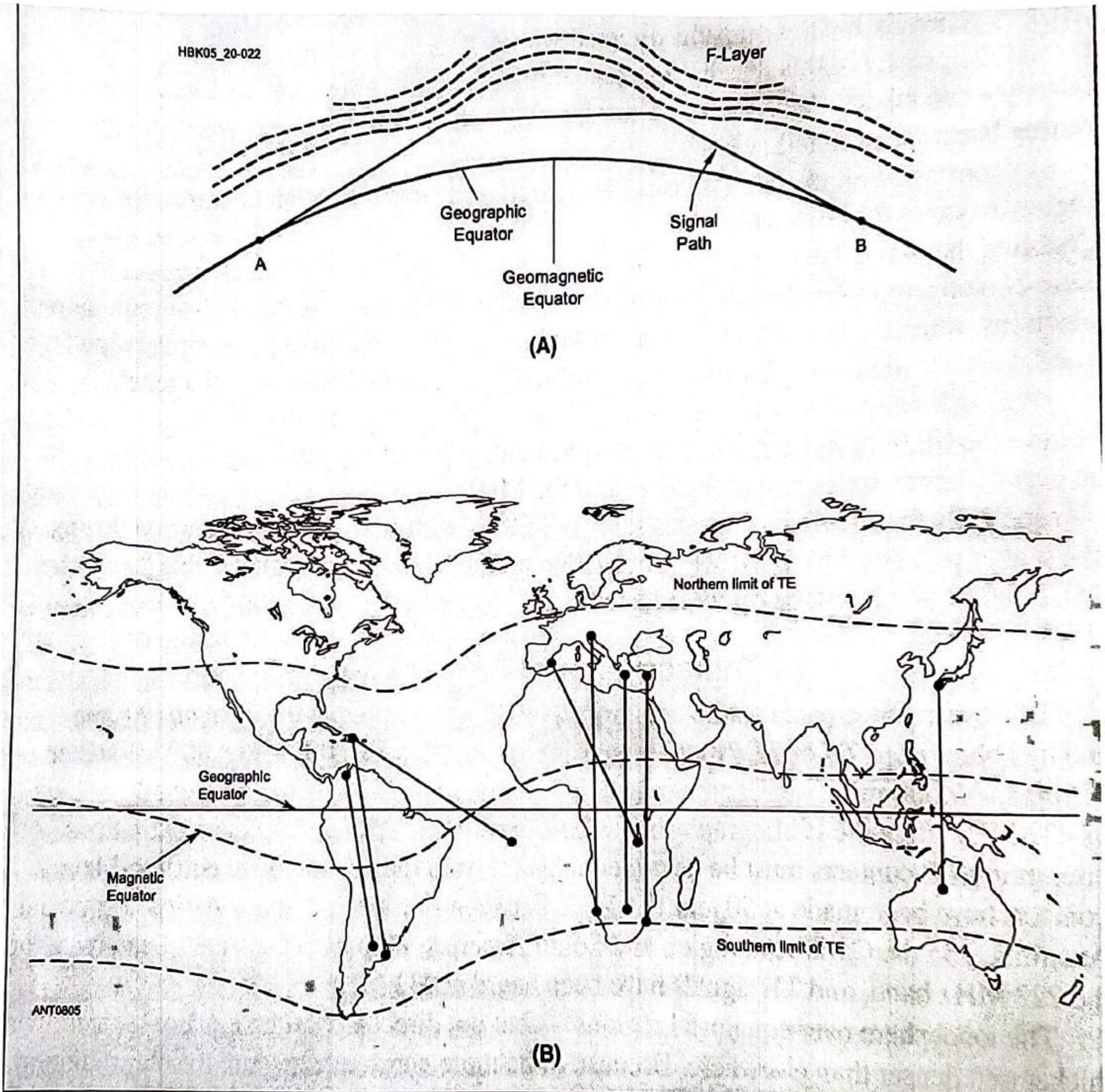


Figure 40 — Cross section of a transequatorial signal path in A, showing the effects of ionospheric bulging and a double refraction above the normal MUF. Transequatorial propagation takes place between stations approximately equidistant across the geomagnetic equator as shown in B. Distances up to 8,000 kilometers (5,000 miles) are possible on 28 through 432 MHz. Note that the geomagnetic equator is considerably south of the geographic equator in the western hemisphere.

FIGURE 7