Australian Government
Department of Defence
Capability Acquisition and Sustainment Group

Indirect Fire Support (IFS)

ADF Land Fires Platforms and Radio Link Development

The digitisation of the ADF IFS Land Platforms

An overview of the ADF Land Fires fleet and the effort to reinvigorate HF within the Ground Network.

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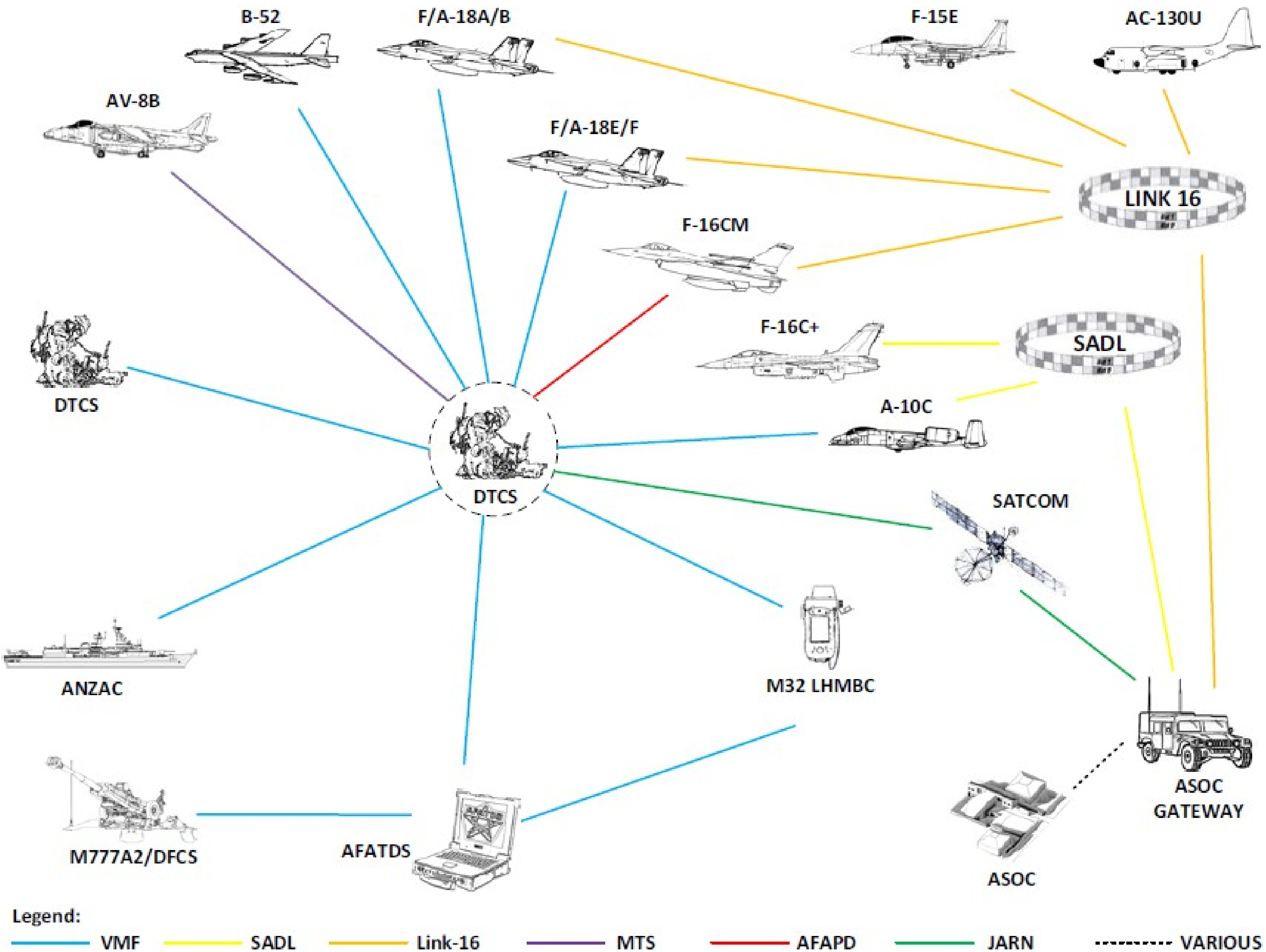
- Combat Support Systems Program Office (CSSPO) are responsible for the acquisition and sustainment of Land Domain Indirect Fire Support platforms and their integration into the Land Fires Network.

- Using VMF; the ADF has been able to fully digitalise the Call For Fire mission thread from the Forward Observer to the Fire Support Element.

Indirect Fire Support – All Platforms



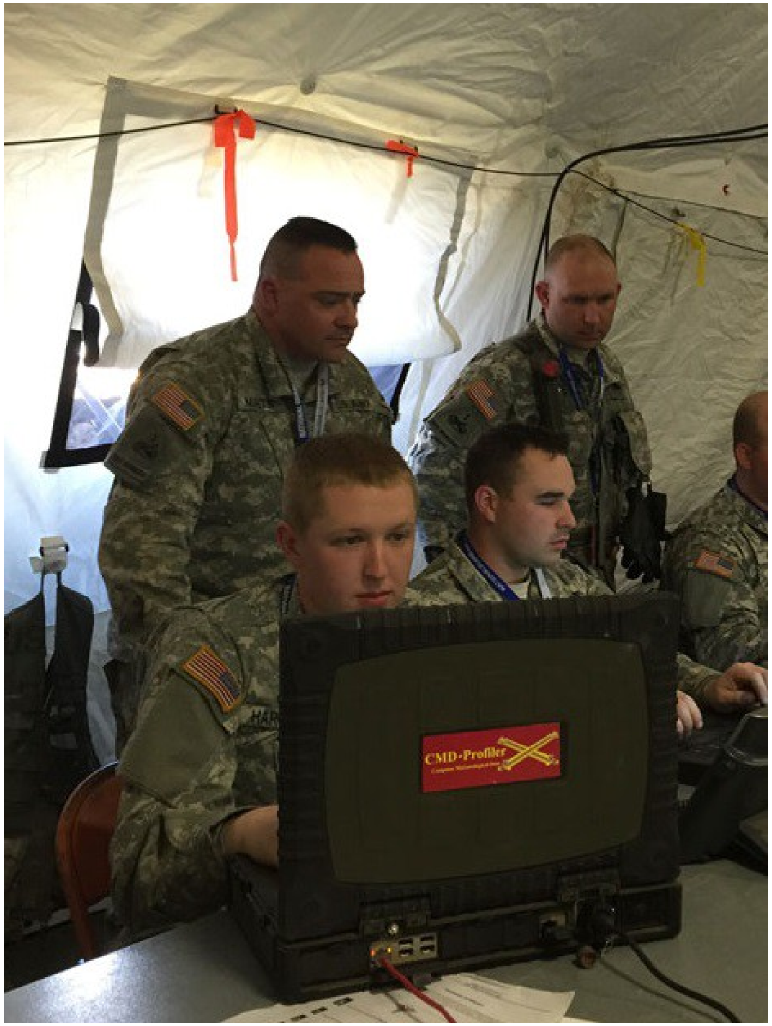
Current IFS Land Platforms include;

- M777A2 – 155mm Howitzer with a Digital Fire Control System (DFCS)
- M32A1 – Lightweight Handheld Mortar Ballistic Computer (LHMBC)
- AFATDS – Advanced Field Artillery Tactical Data System
- DTCS – Digital Terminal Control System

- A digitally enabled Fire Support Element with the Digital Fire Control System (DFCS).
- DFCS enables each gun to receive digital mission data to prosecute a location with the desired effect.

- Land 136 is currently replacing the in service mortar shown to the left, along with introduction of the M32A1 LHMBC

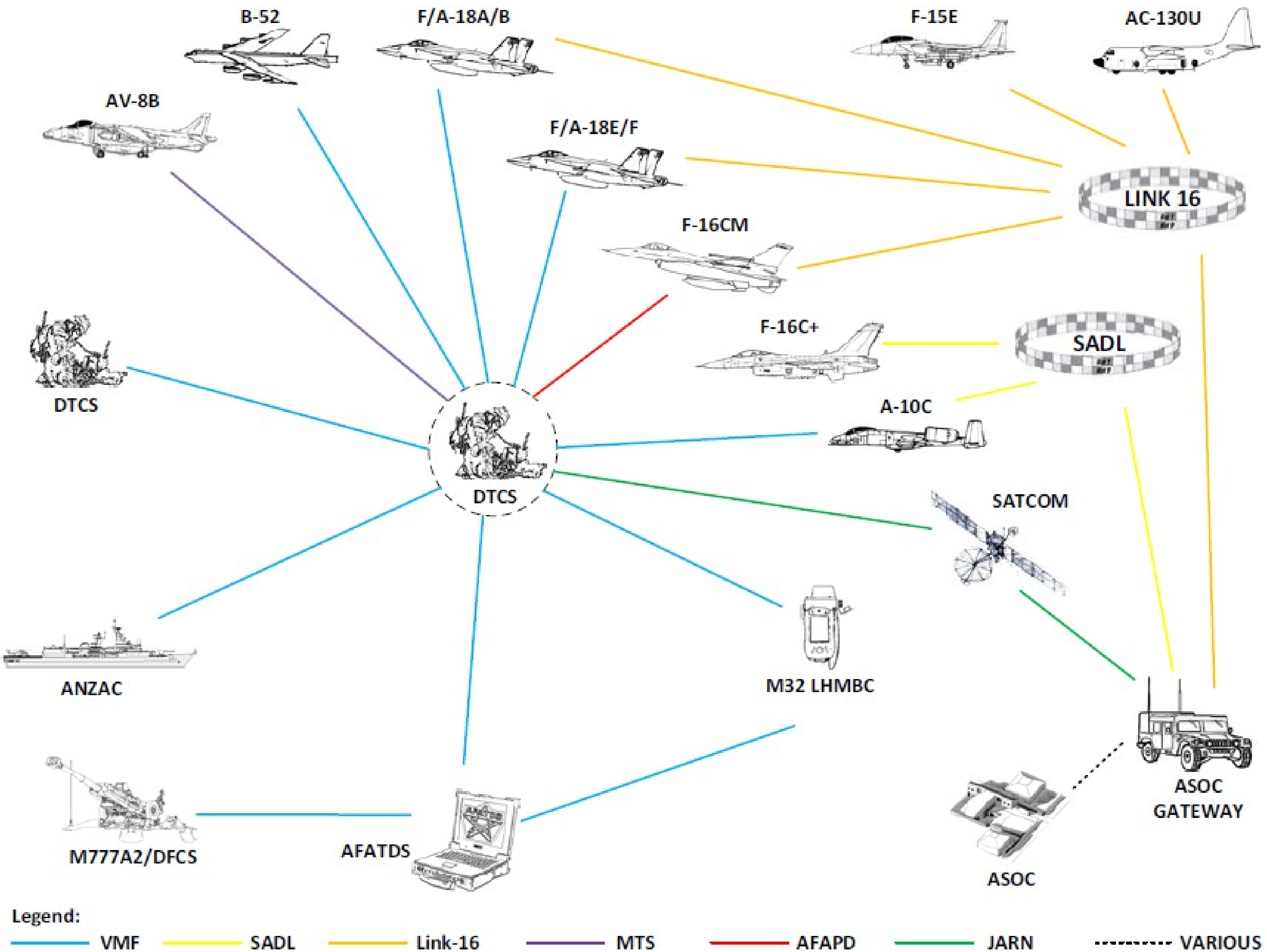
- M32A1 enables the mortar platoon to be a Fire Direction Centre and a Fire Support Element for Mortars within the Land Fires Network.



- AFATDS is the Battle Management System – Fires (BMS-F) Command and Control platform used across the ADF.
- Software based solution.
- Used for situational awareness, operations planning, fires and effects processing, and fire planning.

- A sensor node (DTCS) in the Fires Network.
- An all digital solution to initiate Indirect Fire Support from Artillery, Naval Gun Systems or Air Platforms.
- Complex and heavy single solution product undergoing replacement with Land 17 Phase 2.

Indirect Fire Support - DTCS Platform Interoperability



- Size, weight and power of the in-service DTCS equipment are identified as key factors to improve.

- DTCS can talk across twelve different VMF stacks, which consist of a standard defined message, header and protocol, to achieve interoperability with ADF and coalition platforms.

Description	Message Standard	Message Header	Protocol
F/A-18F	VMF6017A	MIL-STD-2045-47001C	MIL-STD-188-220C
AFATDS	MIL-STD-6017A	MIL-STD-2045-47001C	MIL-STD-188-220C w/ N-Layer Pass
ANZAC	MIL-STD-6017A	MIL-STD-2045-47001D CH 1	MIL-STD-188-220D CH 1

- Key capability to Beyond Line Of Sight (BLOS) communications for ADF is the use of SATCOM.

- A solution to the SATCOM denied environment, to maintain key capability in the Digital Indirect Fires space, is the use of HF Communications.

Our Current HF Radio Status

- Our in service HF equipment is mainly 10 to 30 years old.
- Developed for different requirements, at different state of technology.

Question: has anything changed over the last 30 years ?

- HF theory has made significant advances
- Modern SDR radios are very capable (direct sampling)
- Masts from advanced composite materials
- Antenna modelling tools – powerful and widely used
- Propagation theory has advanced (especially NVIS)
- Data is used much more, and voice is used less
- Antenna matching to transmission line has changed
- RADHAZ rules have changed

Answer: almost everything has changed, except us …

How To Improve Our HF Link ?

Are We Unique ?

We work for Indirect Fire Support (IFS).

Our HF Link requirements are similar to most other divisions within Army.

Outcome of our research can therefore help most HF users.

Challenges ?

We want high performance HF link , without RADHAZ issues.

Current military HF equipment on offer is non ideal.

Buying bits and pieces leaves us with system integration problems to solve.

Developing and testing equipment resolves system integration issues.

Opportunities ?

Australian companies can use this opportunity to develop and deliver high performance HF antennas for military use.

How To Improve Our HF Link ?

- Action Plan For Indirect Fire Support
- Define new requirements for HF link
  - Clearly state our current needs
  - Include new needs and upcoming projects
  - Catch up with current state of technology
- Review in service HF equipment
  - RADHAZ, performance, safety, ease of use
  - Modify HF equipment to suit new requirements
- Review Our Training
  - Review current practices and identify problems
  - Develop new HF training materials
- **Current status: all tasks completed**

New Requirements

- Network type: Point-to-multipoint
- Range:
  - AFATDS Units: 0 to 40 km
  - BDE JFT: 0 to 60 km
  - Future upcoming project: 300 to 500 km
- Mobility:
  - AFATDS Vehicle Mounted & Stationary (90%)
  - AFATDS Dismounted (10%)
  - DTCS Forward Observer – man packs
- Traffic Requirements:
  - Data (voice is required only for CONOPS)
  - Data type: VMF + AFATDS

New Requirements

- **AFATDS HF Link Data Requirements:**
- **Baud rate**: 1200 BPS (preferred 2400 BPS or higher)
- **Latency** : 30 seconds
- **Skip zone** : not acceptable (coverage loss) under any conditions

- **Link must be effective irrespective of:**
  - type of terrain
  - time of day
  - geographical location
  - season of the year
  - disturbances to ionosphere
  - solar cycle progression
  - space weather

Review of In-service HF Equipment

- HF Radio
- **Harris RT-150**
  - Setup is time consuming, not very intuitive.
  - Dynamic range 80 dB (wide spaced)
  - Wideband data is not available

- **Enhanced Defence HF Communications System (EDHFCS) Project**
  - Long range HF radio communications
  - New wide-band HF radio - Harris RF-300H-MP (up to 120 kbps rate)
  - New HF amplifier (1 kW)
  - New HF antennas, masts and CMC chokes
  - IFS is making major contribution to EDHFCS project

Review of In-service HF Equipment

- **Forward Observer (FO) Antenna**
  - FO needs very lightweight antenna, easy to setup, solid performance.
  - Example: squid-pole OCF antenna
  - Only man pack whip available – very poor performance, RADHAZ issues.
- **Clark Antenna Mast**
  - Very heavy and hard to setup, too short for lower HF
  - Clever antenna design must reduce mechanical loads on mast
  - Modern composite materials enable design of lighter, taller masts
  - Example: SpiderBeam telescopic fibreglass masts (12,18, 22 and 26 m)
- **RT-150 Man-pack Whip Antenna**
  - Very low efficiency, especially on lower HF
  - Very high reactive field (RADHAZ issues)
  - Very poor NVIS performance
  - Line Of Sight (LOS) only

HF Antennas AS-F101 / 104 Review

Designed some 30 years ago – very low performance

1. Few antenna configurations are possible – none very effective
2. Inverted vee dipole is the only configuration suitable for IFS
3. Wire spools are very heavy, and may require separate vertical support
4. Excess antenna wire can not be detached to reduce weight
5. Wide-band impedance match – resulting in very low efficiency
6. Uses loading resistors and drives RF currents into ground
7. RF is wasted on losses, in order to get acceptable VSWR
8. Very low efficiency demands using maximum power
9. Using high power often leads to RADHAZ problems
10. No transmission line decoupling (RADHAZ problem, degrades performance)
11. Very heavy antenna (20 times too heavy – so it requires strong heavy mast)
12. Significant ground losses , very low efficiency
13. “BALUN” problematic – poor TL decoupling leads to RADHAZ problems
14. Too much focus on VSWR - the only thing most customers can evaluate.

- **Good news: all these problems are very easy to fix !**

PMV Antenna Review

- Vertical whip antenna mounted on vehicle, uses remote antenna tuner for matching.
- Vehicle does not act as a ground plane, but as counterpoise.
- **Massive problems for IFS**
    1. Antenna is too short and too low for lower HF (problems tuning under 3.3 MHz)
    2. Antenna is too low for lower HF (very low efficiency)
    3. Antenna pattern is not suitable for NVIS (minimum at high elevation angles)

- Few poor fixes were attempted, but addressing only problem 3 (?????)

- **Poor Fix 1: Antenna Bent Forwards**
- Horizontal and very low over conductive plane
- Current image of opposite polarity causes massive field cancelation
- Highly reactive impedance and poor coupler efficiency

- **Poor Fix 2: Antenna Bent Backwards**
- Only slightly improves NVIS, but at expense of LOS and GW

Main Problem: Antennas

- Some antenna vendors use unfair advertising.
- Most customers can measure and evaluate only one antenna parameter: VSWR.
- Antennas are made for good VSWR, using wideband low efficiency matching systems.
- Most often RF losses actually make VSWR look much better.

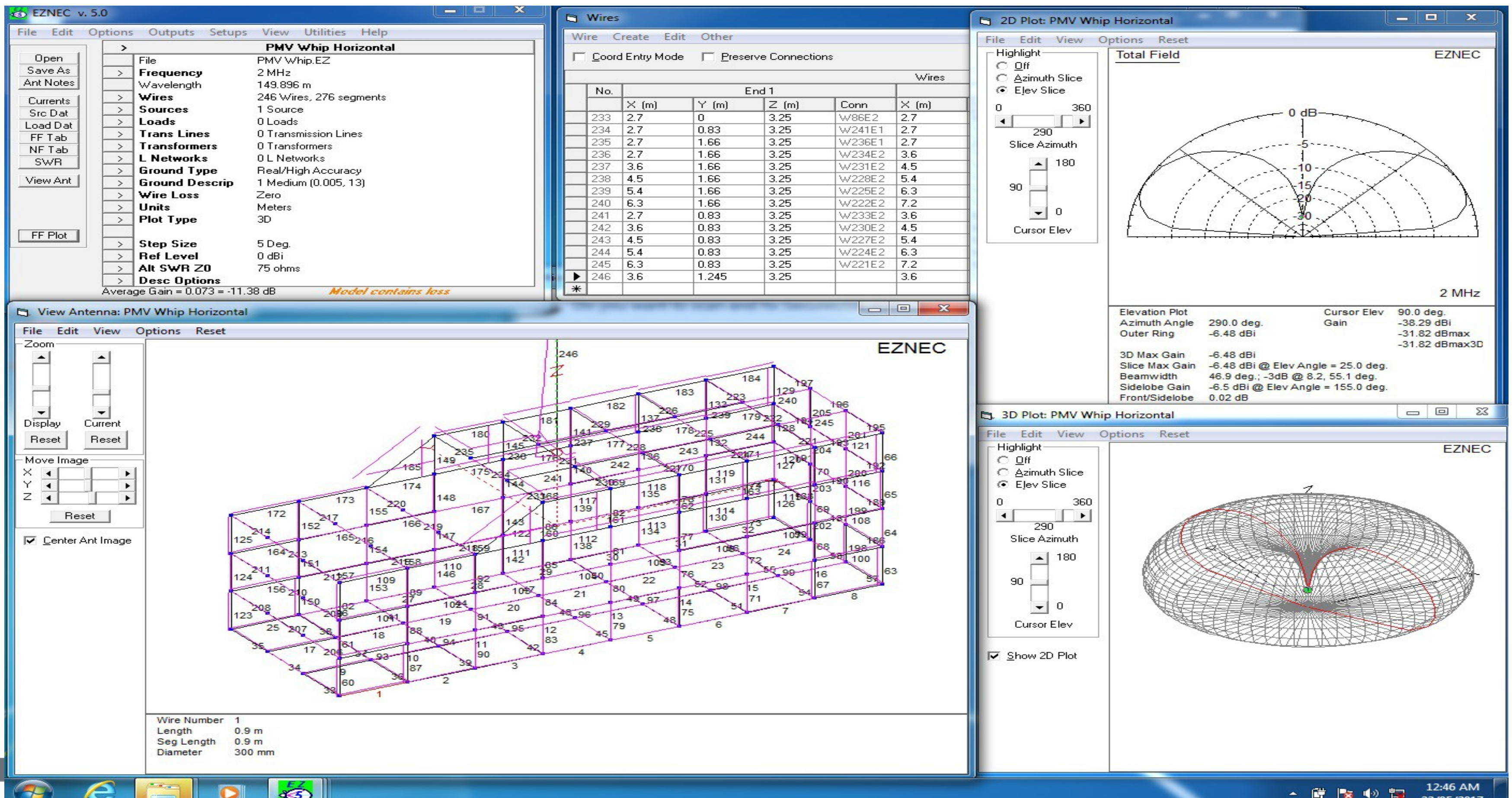
- Example unfair advertising: Antenna 1
- Vertical whip only 1.2 m long, gain at 1.8 MHz G(1.8)= -2dBi
- Radials not mentioned

- Example fair advertising: Antenna 2 $4,000
- Vertical whip 8m long, At 1.8 MHz gain G= -2dBi
- At least 16 radials required (16x40 = 640 m of wire)

- Both antennas advertise the same gain, but antenna 1 is much easier to install
- Nobody wants to buy antenna 2, and company can either go broke or join unfair advertising
- **Understand what you are buying, and test before you buy.**

HF Antenna Modelling

- **HF Antenna Work Completed by IFS:** Analysis, Testing and Design
- **Antenna Modelling:** EZNEC Pro 2 (Method of moments)
- **Antenna Parameters:** Gain, Impedance, Efficiency, RADHAZ, Near Field, Far field



HF Vehicle Models

- Vehicle is counterpoise, not a ground plane (unlike VHF and UHF)
- Vehicle interacts with antenna and ground
- Wire mesh is very accurate for HF antenna modelling
  - Vehicle model typically involves 100-300 wires
  - Developing good vehicle models for HF takes time and effort
- Antenna model typically involves only 1-3 wires
  - It is very easy to add any antenna to existing vehicle models

- Vehicles modelled so far : PMV, G-Wagon, PMICA, ADRHIB, etc.
  - Few antenna mounting options investigated
  - Rear-side mounting is most often the best option

HF Antenna Models

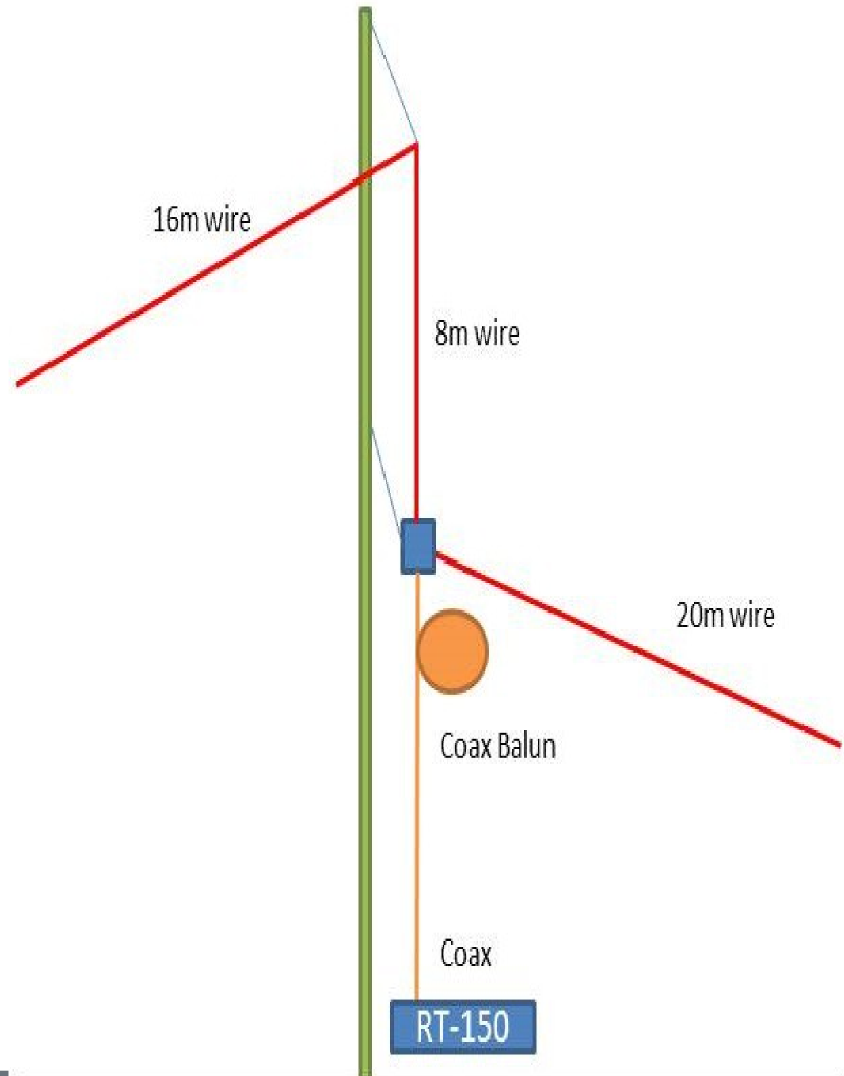
- **Antenna Model For Man-pack Whip**
- Analysis: Impedance , Efficiency, RADHAZ, Near Field.
- Model indicated Near Field RADHAZ problems.
- RADHAZ testing confirmed results of modelling.

- **Antenna Model For AS-F101 and AS-F104**
- Model indicated possible problems with transmission line (TL) decoupling.
- Model was optimised for performance with few simple modifications.
- Testing confirmed problems with TL decoupling.
- Modified AS-F104 antenna was developed to overcome problems, and tested.
- Tested to work very well (2 W only, 70 km link, over Macedon mountain range)

- **Antenna Model For PMV Vertical (up, bent forwards and backwards)**
- Model indicated problems at lower HF : too short, too low, NVIS pattern not suitable
- Model was optimised for performance, including one simple modification
- Simple solution delivers 15 dB improvement.

Simple Fix For AS-F101/104

- **AS-F101 & AS-F104 Current Problems**
  - No TL decoupling (RADHAZ, poor performance)
  - Very heavy (20 times too heavy, needs strong mast)
  - Significant ground losses , very low efficiency
  - Wideband "BALUN" (very low efficiency)
- **Design Goals**
  - Effective antenna for all modes - NVIS, LOS, GW
  - High gain, high efficiency, no RADHAZ issues
- **Important Changes**
  - "BALUN" axed
  - TL decoupled with coax choke (RADHAZ gone)
  - Composite mast (SpiderBeam 18m)
  - Vertical section to link with vertical antennas
  - Light-weight wire, excess detachable
  - Massive NVIS Gain = 6 dBi
- **Tested over 70 km using only 2W**
- Excellent connection to station using PMV whip antenna.
- Macedon mountain range in between.



Simple Fix For PMV Antenna

- **Current Problems**
- Antenna is too short and too low
- Tuning under 3 MHz is problematic
- Pattern has deep null for NVIS angles

- **Sloping wire added on top of the vertical whip**
- Improved efficiency and gain for NVIS, LOS and GW.
- Easier for coupler to match
- Lower HF efficiency up 15 times
- Good ALE multiband antenna
- Easy to erect using 10m squid-pole
- Counterpoise can replace PMV
- Suitable for Forward Observer (FO)
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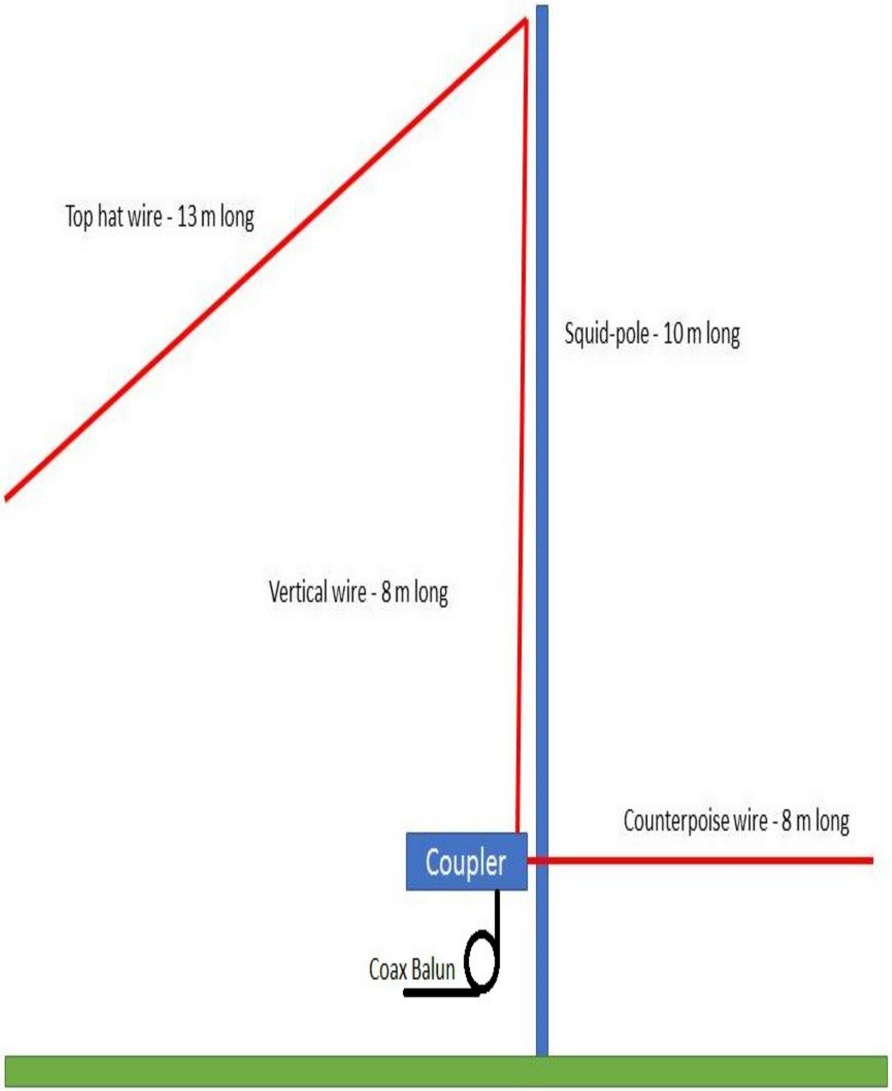
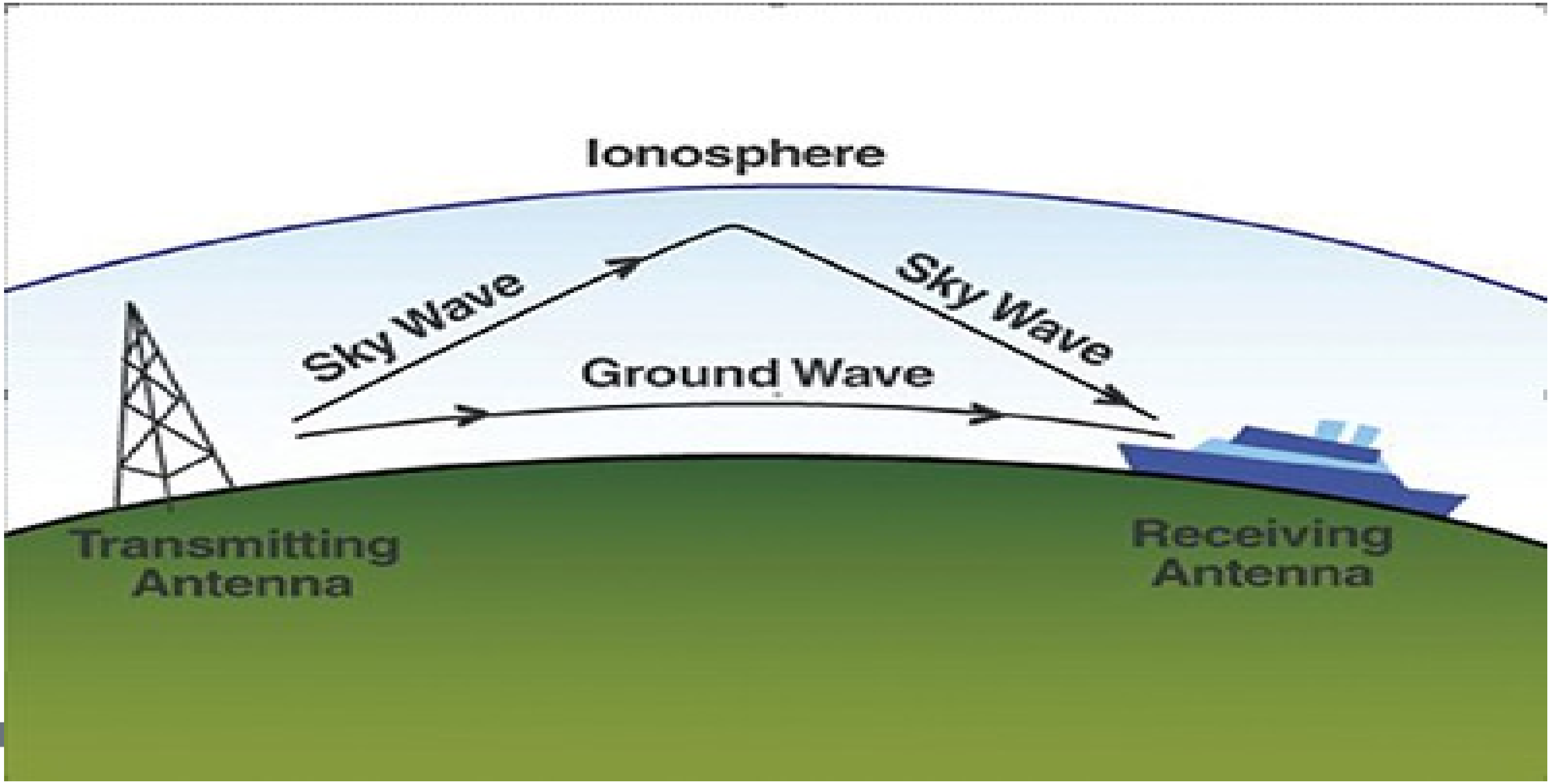
- RADHAZ benefits:
- Better efficiency => needs less power
- Maximum current moves higher up
- Reactive field reduced



Propagation Modes

- **Range :** IFS requires HF link over distances up to 60 km
- **Range extension planned** : 500 km.
- **Terrain Type**: any - complete coverage is required, irrespective of terrain type.
- **Ionosphere Condition**: any – complete coverage at all times
- **Not acceptable**: Shadowing, Skip zones, Fade Outs



HF vs VHF and UHF

VHF & UHF – the only mode is LOS. Easy to plan. Simple maths for link analysis.

HF - Four modes: LOS, GW, SkyWave and NVIS. Link analysis does not work.

- Link affected by many factors:
  - Terrain features
  - Constantly changing ionosphere
  - Time of day
  - Geographic location
  - Travelling Ionosphere Disturbances (TID)
  - Solar cycle progression (12 years period)
  - Space weather (includes variation, disturbance and “events” like CME)
  - Weather (storms up to 1,000 km away)
  - Atmospheric noise variation is over 80 dB, making link analysis useless.
  - Antennas interact strongly with ground, equipment and personnel.
  - GW and NVIS are optimal at lower HF
- RADHAZ analysis is often very complex.
- TL decoupling can be complex, especially at lower HF.
- Wire antennas are very effective at lower HF (effective area like 300 m dish).
- **HF is very complex compared to VHF and UHF**

HF Propagation Modes

LOS – line of sight is limited by terrain, most often under 5 km – **not suitable**.

Ground Wave – poor over hilly terrain, poor beyond 10 km, poor above 4 MHz – **not suitable**.

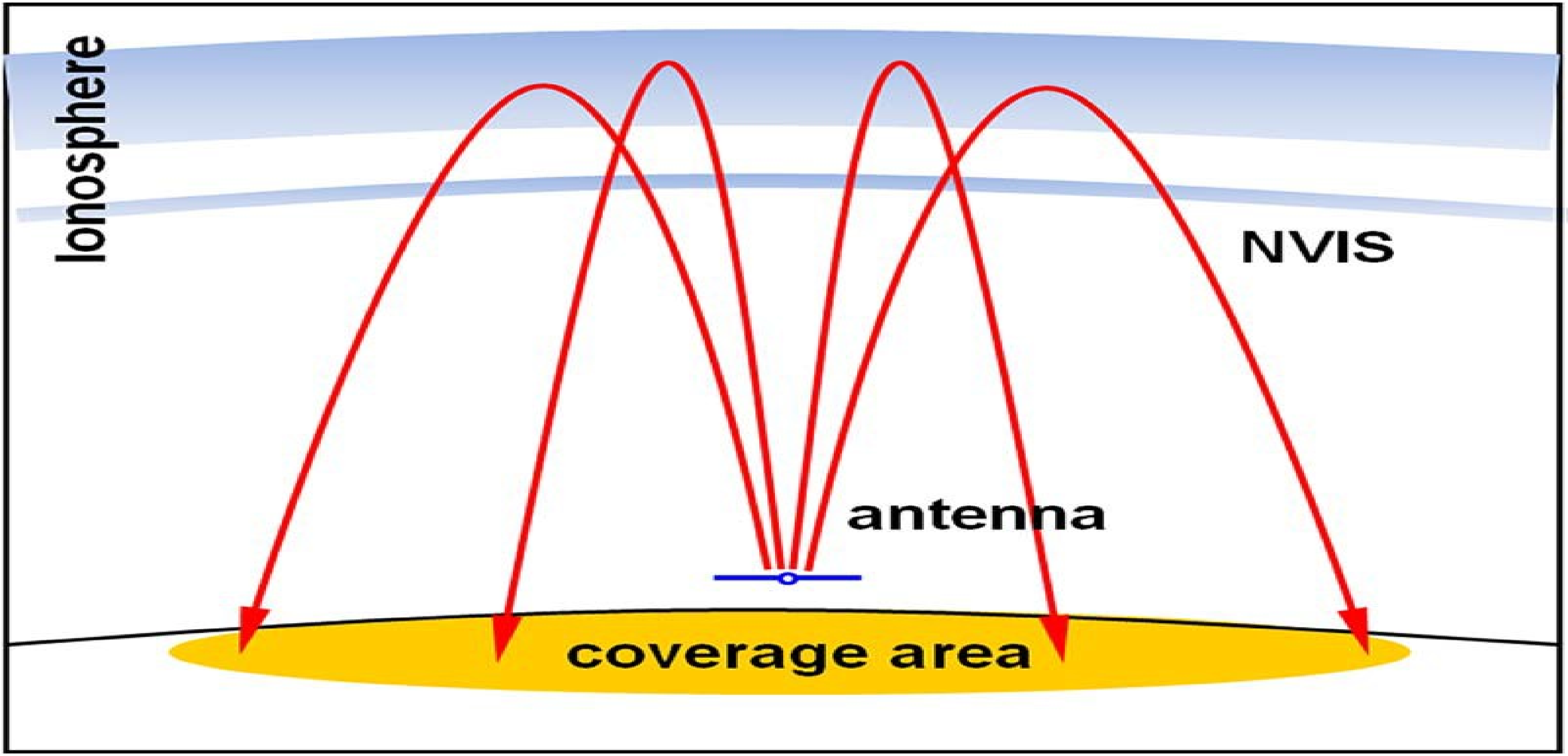
Sky Wave – very large skip zone (no coverage) extending over 1,000 km - **not suitable**.

Near Vertical Incidence Sky Wave (NVIS) - suitable for all terrain types, 500+ km range - **suitable**.

- **NVIS is the only propagation mode suitable for IFS HF requirements.**
- **Critical frequency (foF2) should never be exceeded.**

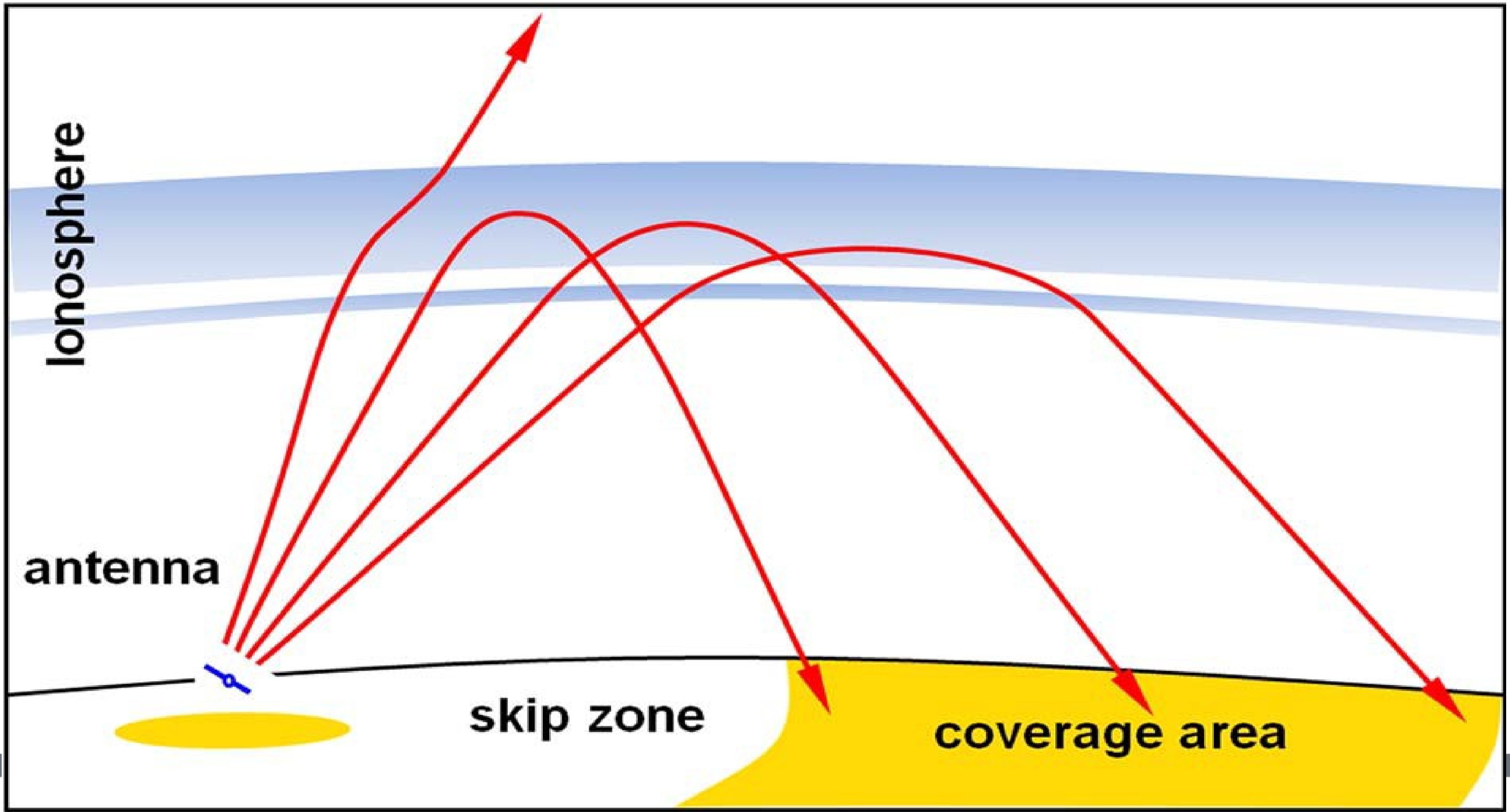
NVIS

- NVIS requires horizontal polarisation, and works well over all types of terrain.
- Typical NVIS frequencies are 4 to 8 MHz during day hours, and 2 to 4 MHz during night.
- Solar Cycle last 12 years – currently at minimum.
- High solar cycle enables higher frequencies (smaller antennas and masts).
- Low cycle means lower frequencies (bigger antennas and masts).



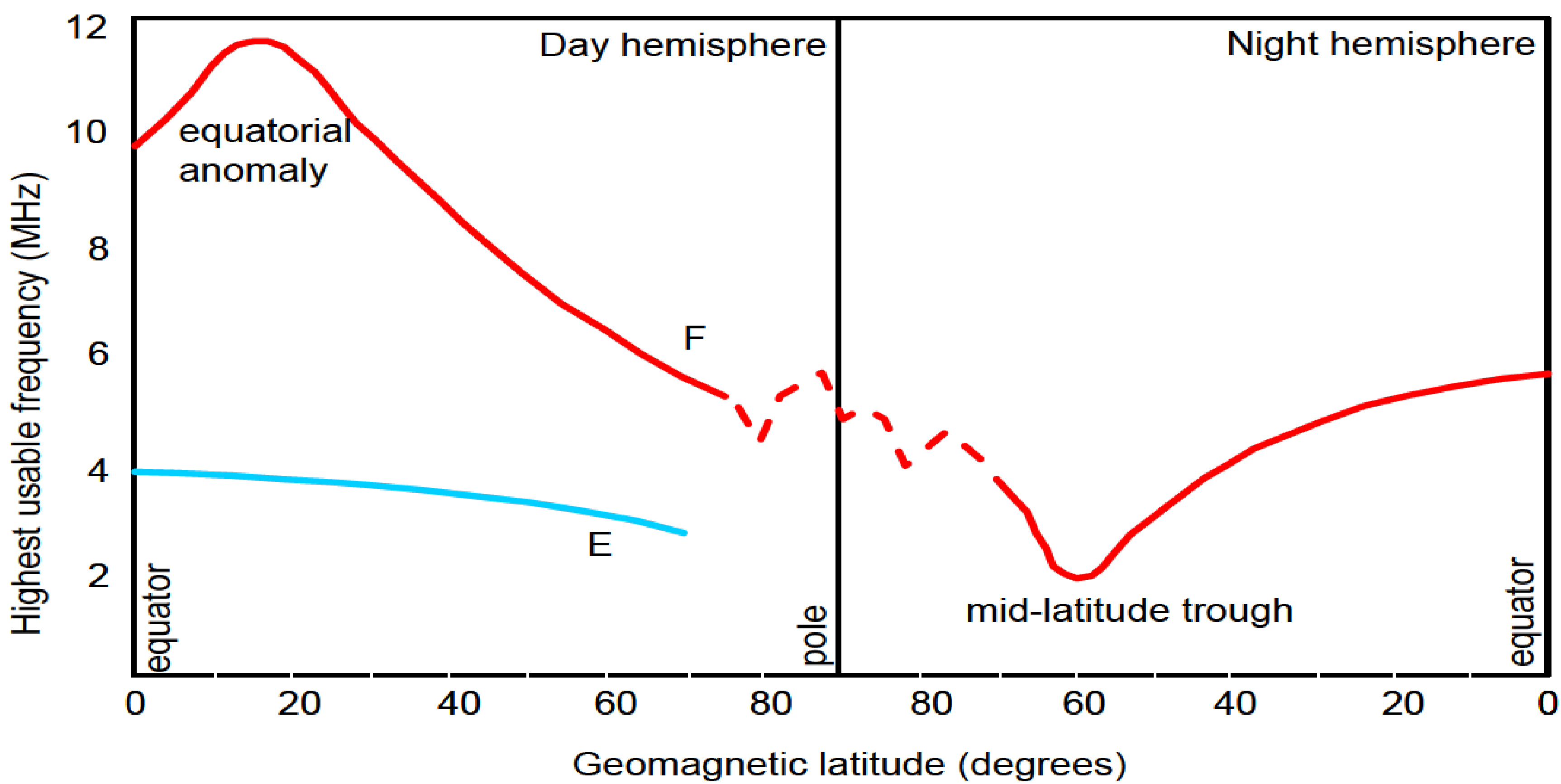
NVIS Critical Frequency foF2

- Critical frequency - the highest frequency at which wave sent vertically up still reflects back.
- Propagation above the critical frequency results in skip zone, with no coverage.
- This is not acceptable for IFS, we must use frequencies bellow critical.
- Some sites have no frequencies under 3 MHz - NVIS link dead 10 to 14 hours a day.



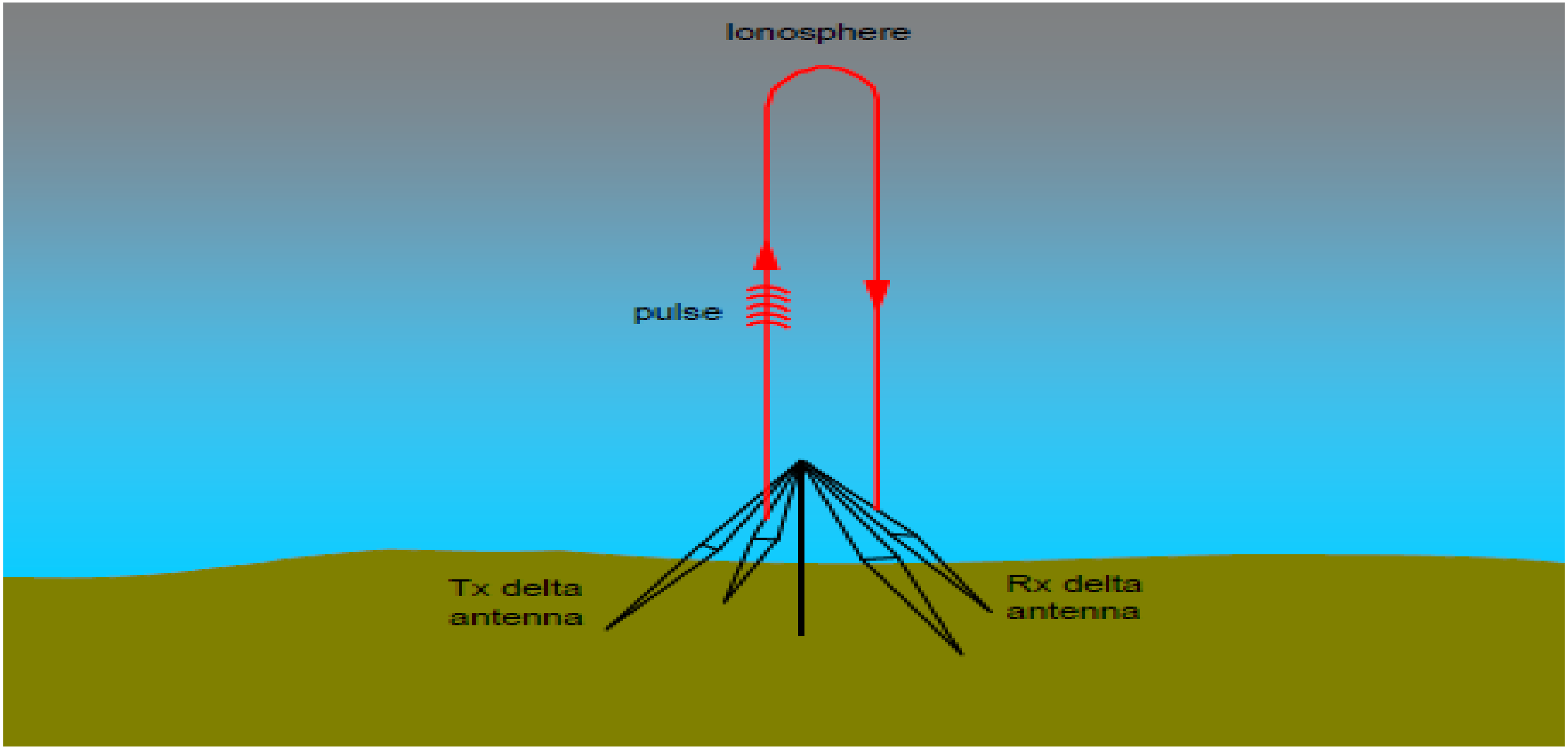
NVIS Daily Variation

- Example of NVIS frequency daily variation is given in Figure bellow.
- Critical frequency for “ordinary wave” and F2 layer is customary used on these graphs (foF2).
- Higher frequencies are more convenient due to: smaller antennas, smaller masts, lower noise.
- Higher frequencies are available closer to equator, during day, and during high solar cycle.



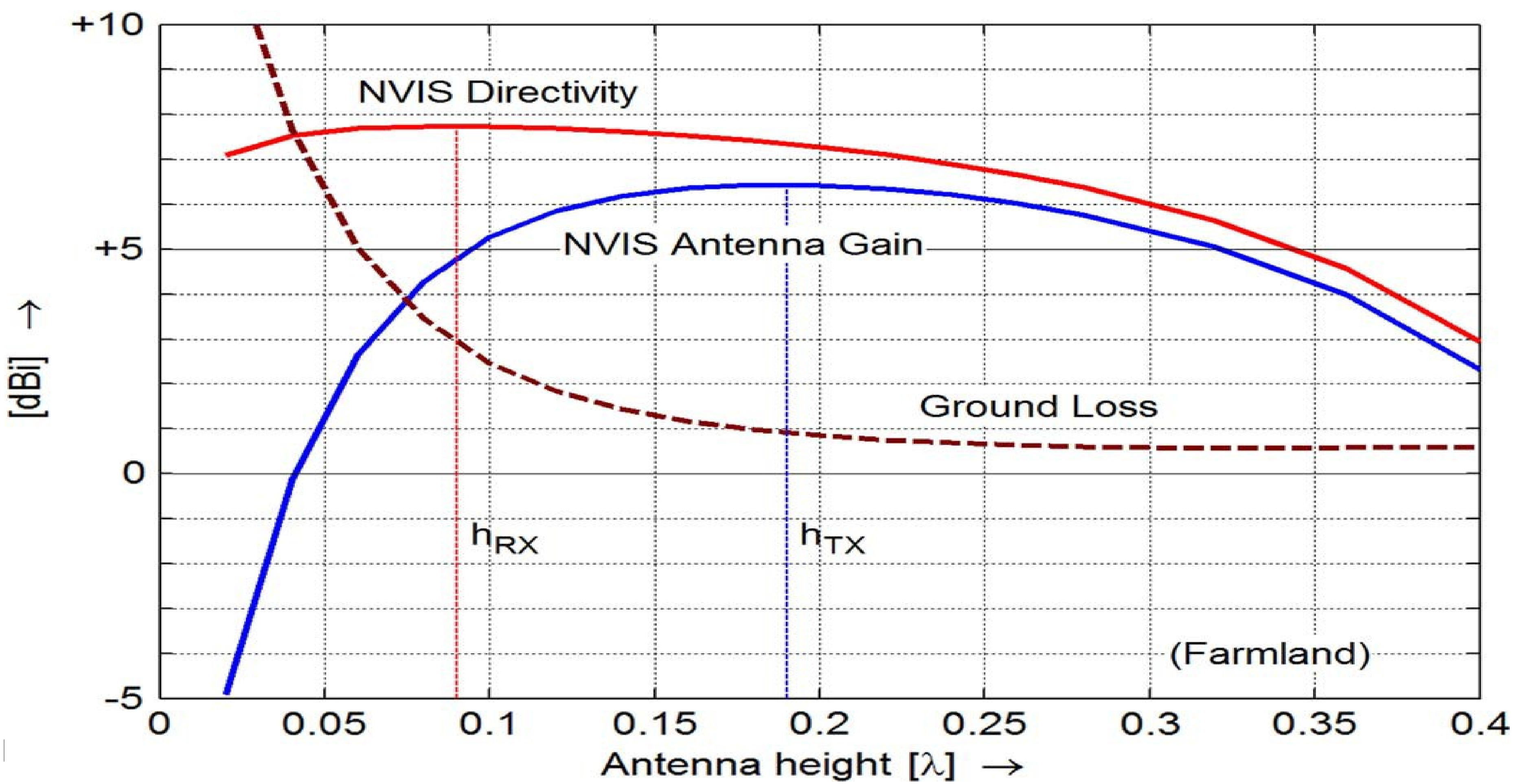
Measuring Critical Frequency foF2

- Ionosonde - measures critical frequencies, by sending signal vertically up and detecting reflection.
- Many ionosodes located worldwide produce real time world map of ionosphere.
- Critical frequency foF2 depends on electron density in F2 layer.
- Alternative method uses Total Electron Density (TED), easily measured by GPS signal propagation delay.
- Correlation between TED and foF2 has been developed, and this lead to neglecting of some Ionosondes.



NVIS Antenna Height

- Optimum NVIS antenna height is 0.18 wavelengths (WL), which is 27 m for 2 MHz.
- Smaller masts are much easier to install, and we may need effective compromise solution.
- Antenna modelling shows -3dB loss for 0.06 WL height, and 27m is reduced to 9 m.



Automatic Link Establishment (ALE)

- ALE is great tool for long distance communications, involving multiple hops and time zones.
- ALE can help by finding the best link frequency in our channel list.

- **In order to function, ALE requires:**
  - List of suitable frequencies
  - Antennas effective for optimal frequency
  - Antennas suitable for optimal mode of propagation

- **Some Common ALE Problems**
  - Allocated frequencies can be far from optimal
  - Allocated frequencies above critical foF2 - the worst problem, creates skip zone without coverage
  - Antennas are not effective at optimal frequencies
  - Antennas are not suitable for optimal mode of propagation

ALE For NVIS ?

- **ALE is not required for NVIS, because NVIS planning is very simple**
  - Allocate suitable NVIS frequencies for day and night
  - Allocating only night frequency is sufficient – it will work during the day
  - Day frequency is “nice to have”, it reduces absorption in D layer during day time
  - Setup NVIS antenna effective at optimal NVIS frequencies
    - Impossible with our current in-service antennas
    - Requires some knowledge of modes and frequencies

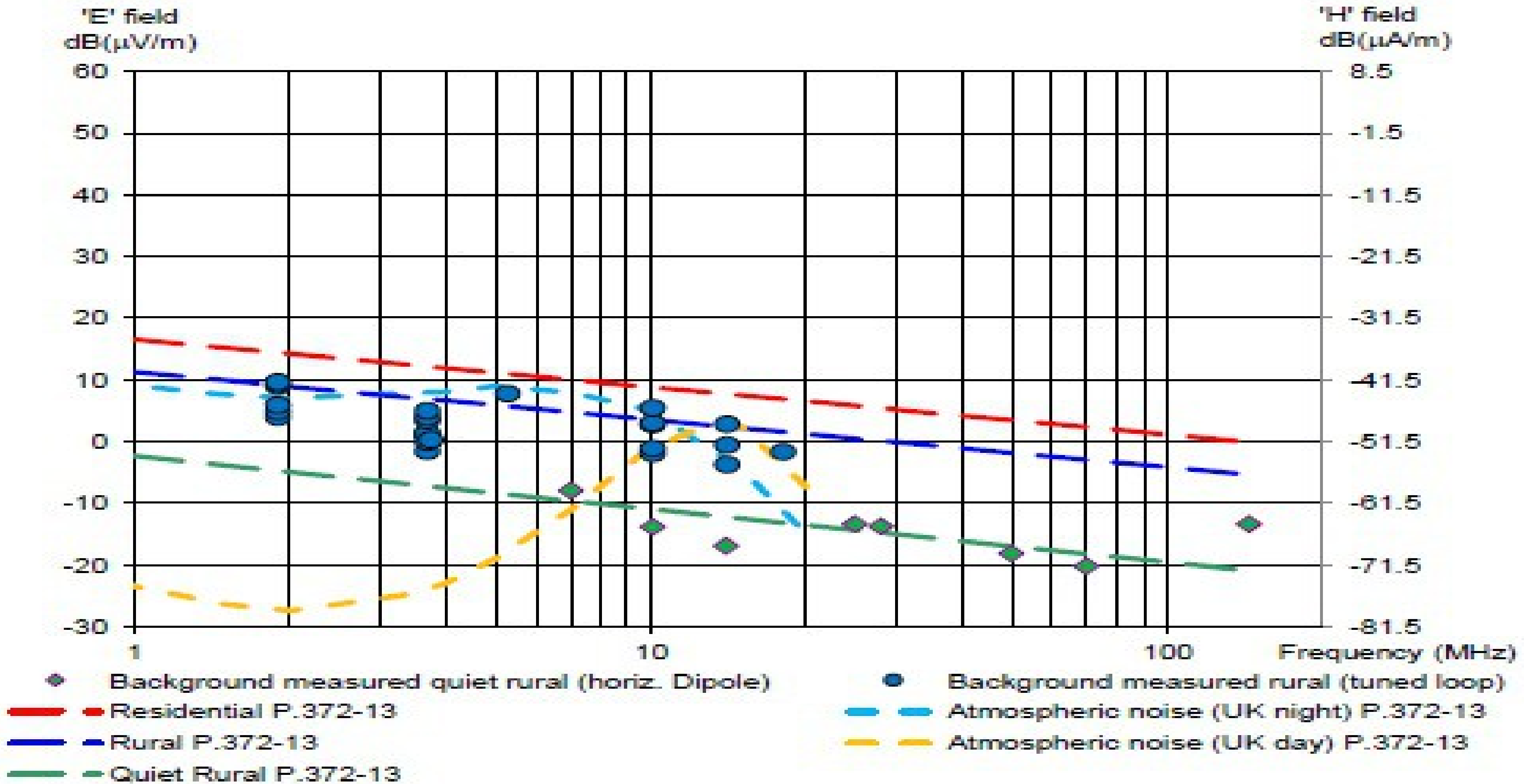
  - Sun cycle is at minimum, and frequency under 2 MHz is required during night
    - Some sites have no frequencies under 3.4 MHz (ouch!)
    - NVIS is dead 9 to 12 hours a day
    - ALE can’t help at all
    - Using frequency above critical leads to skip zone without coverage
    - Skip zone can extend over 1,000 km

Automatic Link Establishment (ALE)

- **Forward Observer (FO) Problems With ALE**
    1. AFATDS uses ALE and PPP protocol
    2. AFATDS sets up RT-150 to use built in router
    3. AFATDS can talk to other AFATDS nodes using HF link
    4. Some FOs use 180-220C protocol (single frequency)
    5. Some FOs can talk to each other using HF
    6. AFATDS and FO can not talk on HF link
    7. FO needs very light HF antenna, easy to setup
    8. ALE needs effective multiband NVIS antenna

Noise Levels

- Noise level on lower HF is high, especially at good NVIS frequencies.
- Residential areas are approximately 20 dB noisier than quiet rural areas.
- Atmospheric noise is dependent on weather, and variation can be over 80 dB.
- Link calculations simply do not work for HF, it is much more complicated.



Questions?