Finding RFI and minimising it’s impact

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RSGB

RSGB 2026 Convention

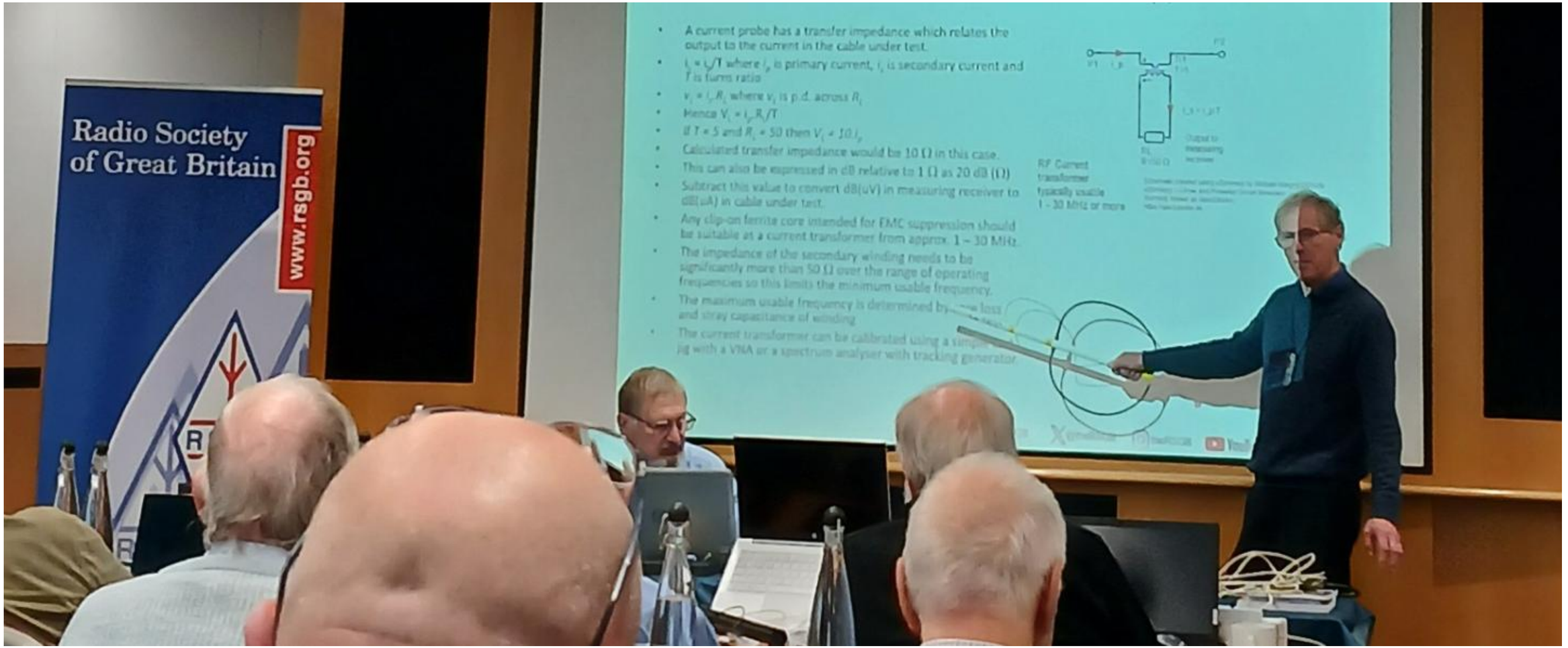
RFI Workshop Timetable

11.00	Introduction Terminology and Guidance JR
	Detecting and locating RFI
	Demo of H and E field antennas radiated emissions – RSP1B
	Signatures help identification - ONOFFON test confirms source
11.45	Assemble & test your own H field (Loops) & E field (whips / patch antennas) JL
	RSP 1B how to set up SDRconnect to detect RFI AC/JR
	Use your own RFI detectors to hunt out RFI sources DT
12.30	LUNCH
13.30	Current transformers and LISNs for conducted emissions DL
	Ways to help minimise the impact of RFI- EMC filters and chokes DL
14.00	Good EMC housekeeping more Examples of RFI signatures JR
14.30	Demonstration 1
15.00	Use of cancelers and diversity reception DT & AC
15.40	Demonstration 2
16.10	What can the EMC committee do to help - Helpdesk? JL
	Ofcom friend not foe how to approach them
16.20	Using AI to help identify RFI - now and future potential
16.30	Feedback on what you have learnt

Terminology

- Electro-magnetic field (EMF)- field produced by an accelerating electric charge it has both electric (E field) and magnetic (H field) components
- Electro-magnetic disturbance (EMD)- an EMF which degrades performance of devices- the cause of EMI or the source
- Electro-magnetic interference (EMI) - the effect of EMD on the victim
- Radio frequency interference - an EMI that affects radio reception
- Harmful interference - RFI that degrades, obstructs or repeatedly interrupts reception
- Electromagnetic EMC - steps to ensure devices can operate together
- Standards - specify limits and testing to demonstrate EMC

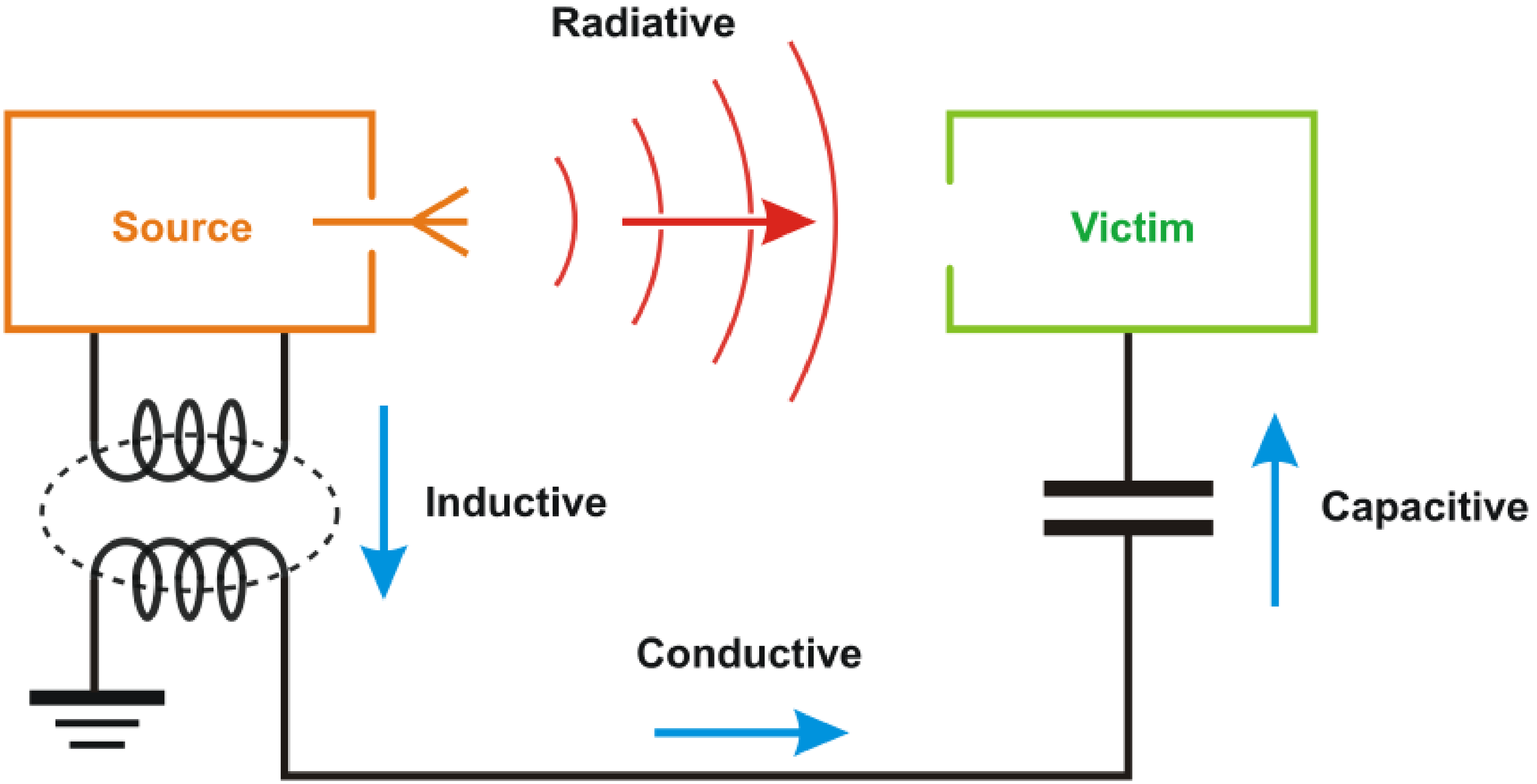
Our first class of 20 at RSGB convention 2026



Why is RFI a problem ?

- All electrical devices produce electromagnetic ***emissions conducted*** &/or ***radiated –*** *some a lot more than others*
- Different electrical devices can be more or less ***immune*** to interference
- Problems arise when emission levels are high enough to effect operation of other equipment
- ***Emission*** and ***Immunity*** standards are designed to allow devices to operate together
- Standards only ensure other equipment can operate as intended – they do not guarantee no RFI
- Radio amateurs and SWLs rely on low background noise but there is no guarantee of interference free reception

Electromagnetic Compatability (EMC)



Equipment for Measuring conducted RFI

- Software Defined Radio, Spectrum analyser or EMI receiver
- **LISN** (Line Impedance Stabilisation Network) for isolating external noise from the mains supply
- Measures conducted RF noise
- Alternatively, use a **current probe** or RF current clamp for cables



Clamp on current probe

- A clamp-on RF current probe is particularly useful for troubleshooting
- This lets you identify **which cable is carrying common-mode RF noise** without disconnecting the system
- Make your own with five turns on a clip-on ferrite





Equipment for measuring Radiated measurements

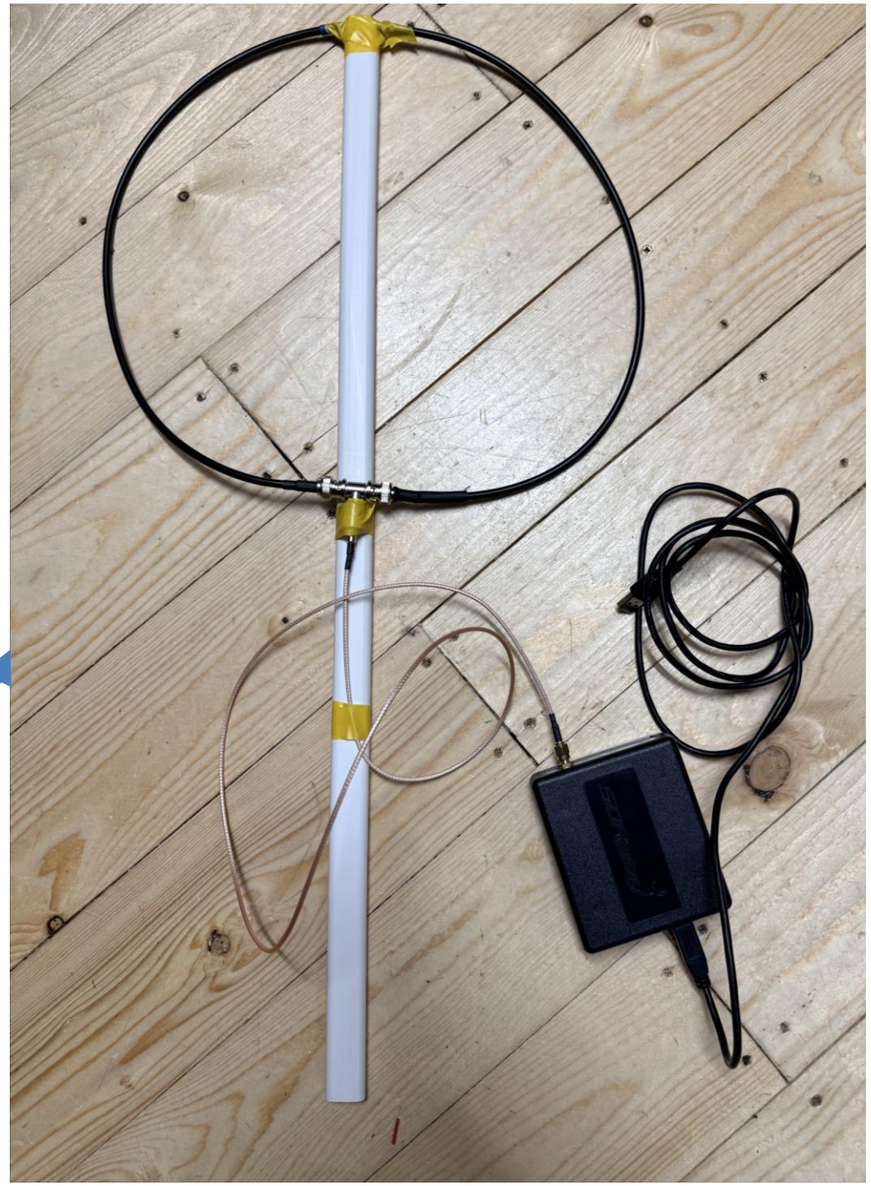




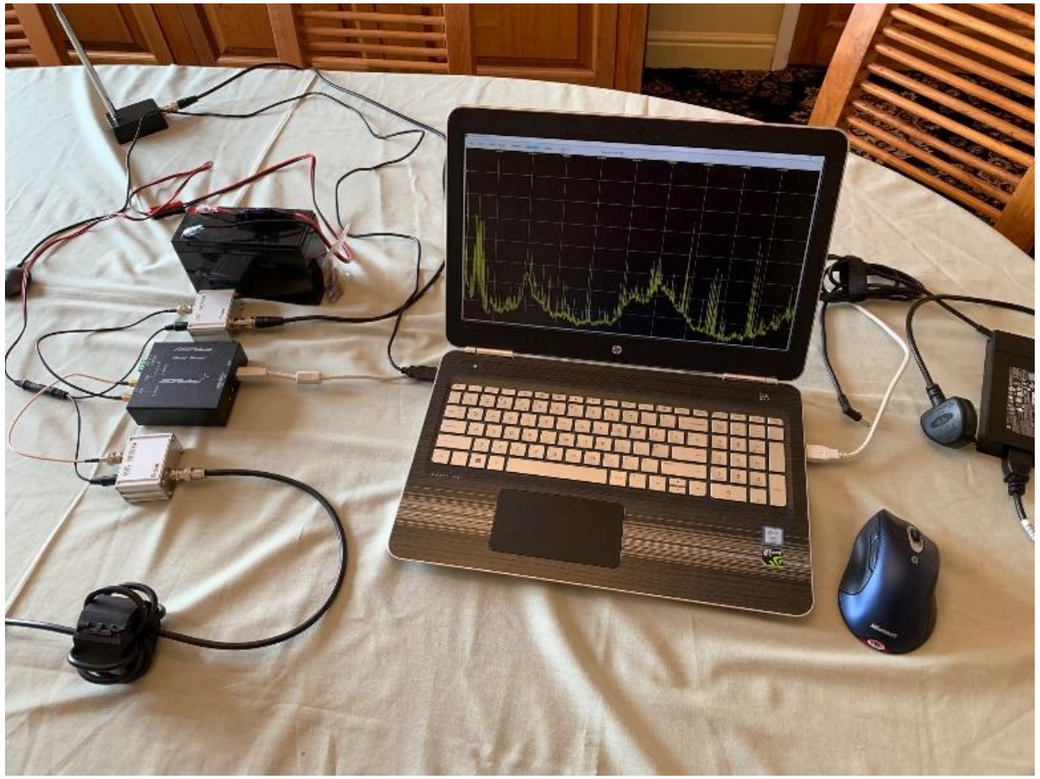
Current clamp

E Field probe

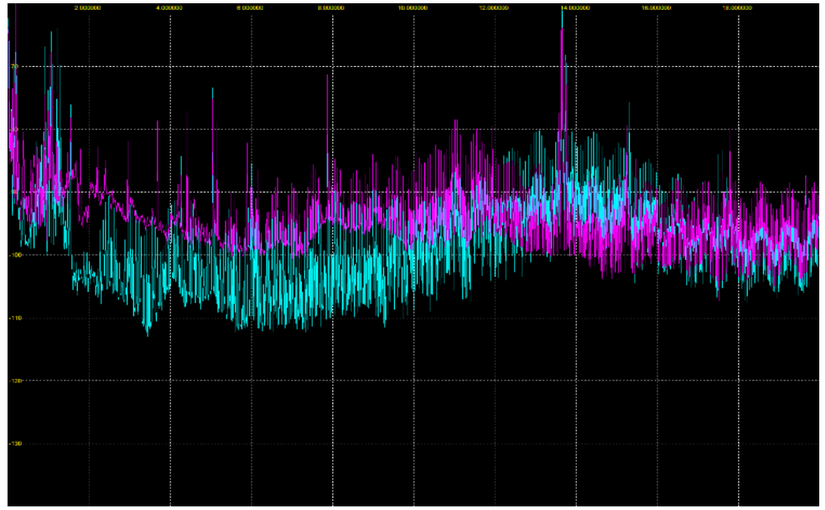
H Field Loop



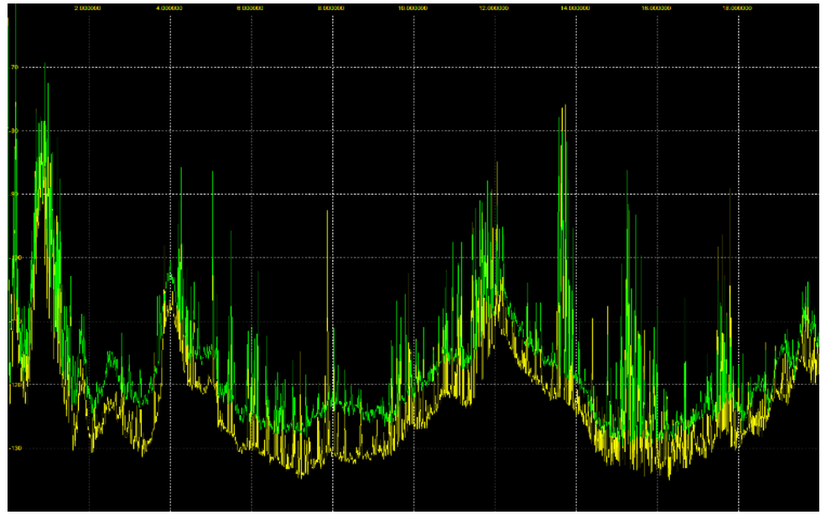
SDRplay Spectrum Analyser



E (whip) and H (loop) antennas show differences in local noise patterns



http://ukraa.com/store/categories/e-field-probe/e-field-active-antenna-short-kit



Wellbrook loop

Beware of finding near field sources which are not the problem –
Use signature of spectrum trace
Check if its inverse square or inverse cubic with distance
Check the signature of the source found is the one you are trying to locate

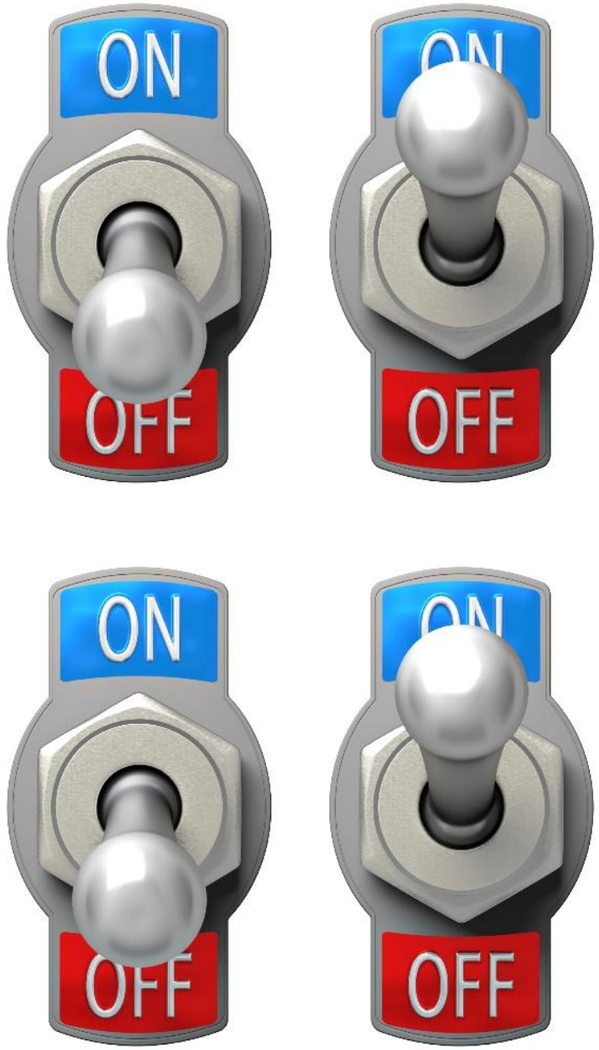
Coaxial cable what does it do?

- How do conducted emissions get into your shack?
- How do radiated emissions get into your shack?
- Coax feeder - what can it tell us?
- How many conductors in a coax feeder?
- With feeder disconnected at RX what noise do we see?
- With centre pin connected but not shield what do we see?
- With feeder connector tightened up what do we see?
- How do we stop common mode RFI?

First things first in tackling RFI problems

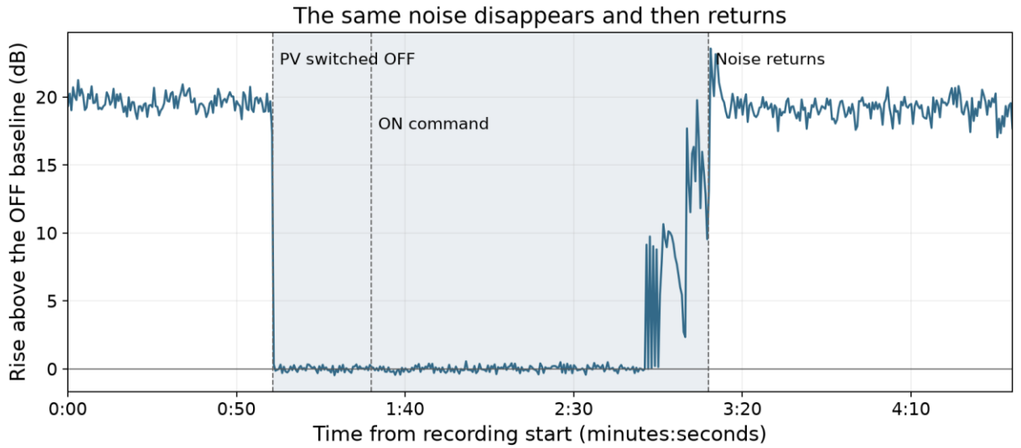
- Make sure nothing in your property is the RFI source
  - Battery operated receiver set up to see the RFI
  - Turn off mains, disconnect telephone line, cable TV, turn off UPSs, switch off laptops, mobile devices, consider moving cars down the road
  - Perhaps also turn off solar inverters, alarm system, emergency lights
  - RFI still present? It's from somewhere else
- Check with a different antenna to see if RFI reduces
- Log the times and strengths of the interference and correlate to electrical apparatus use
- Listen or use SDR to find the extent and nature of interference see
- Look for harmonic separation of RFI

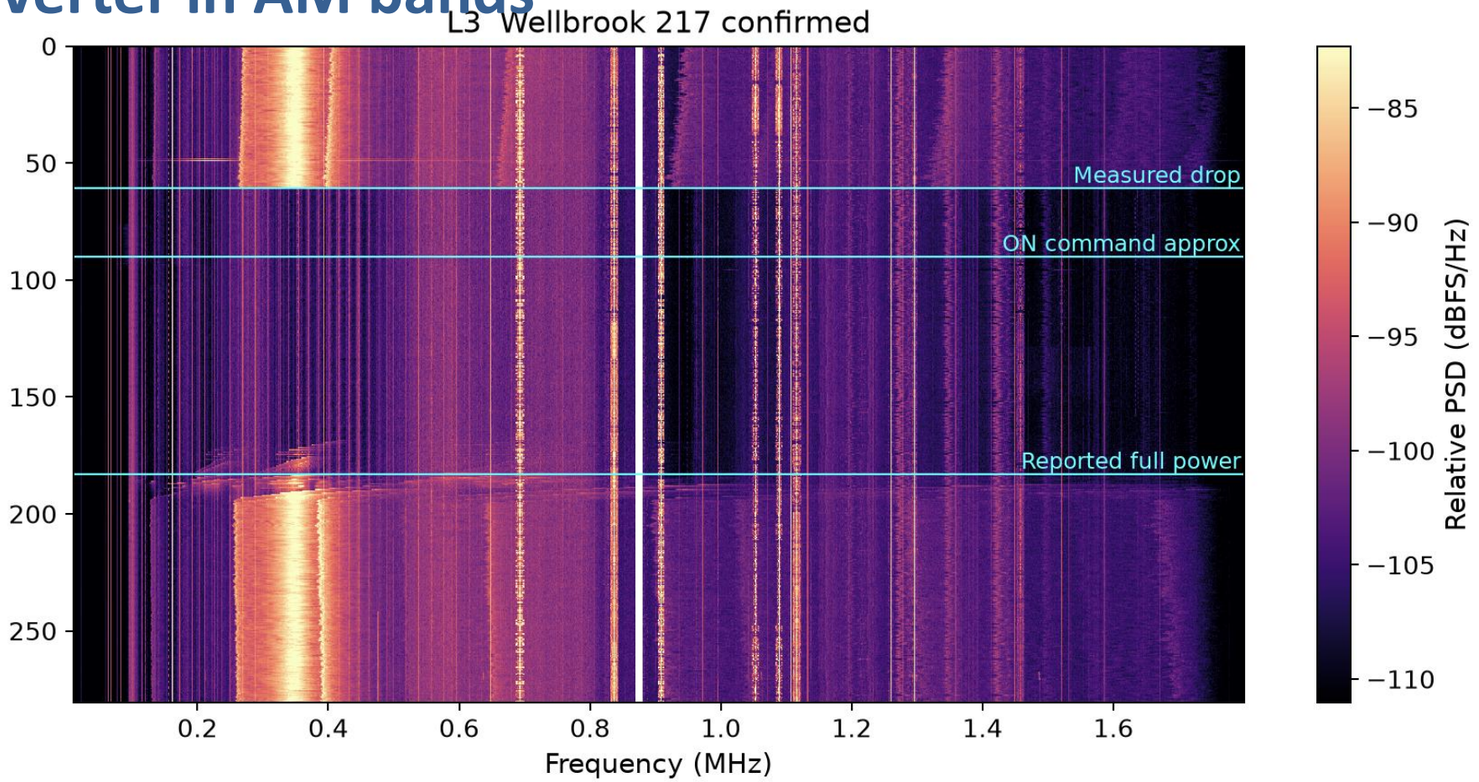
ONOFFON -How to confirm you have found it!!



- **Turn it ON RFI seen / heard**
- **Turn it OFF RFI disappears**
- **Turn it on again RFI re-appears**
- **Beware of devices with standby**

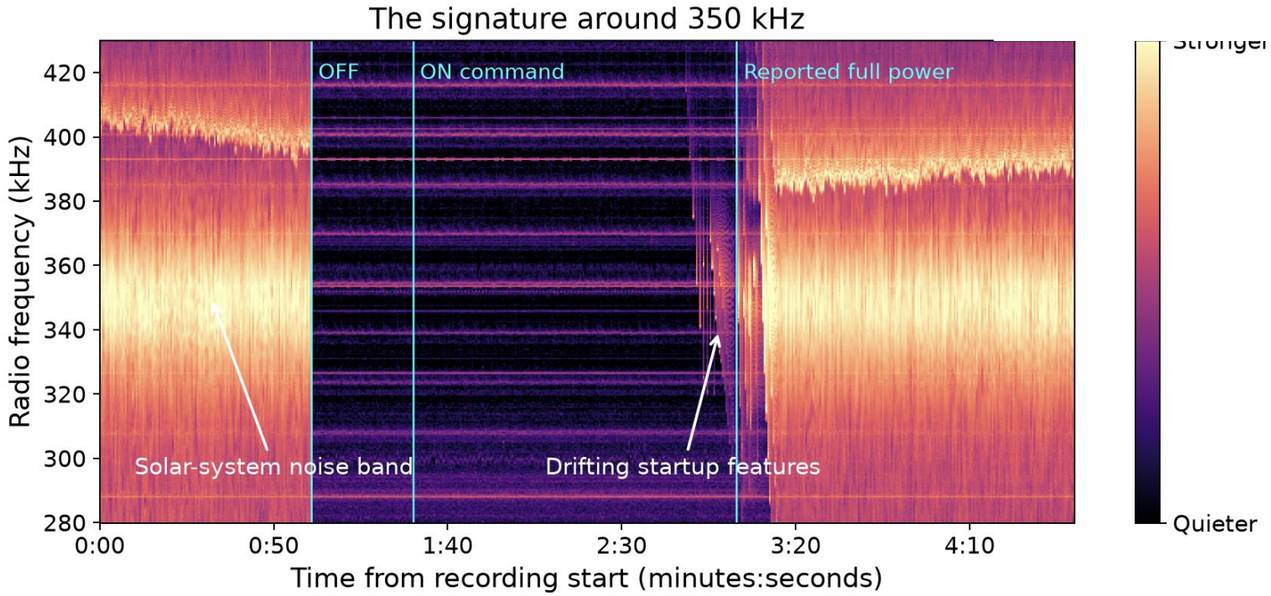
Radiated RFI from ecoflow microinverter in AM bands



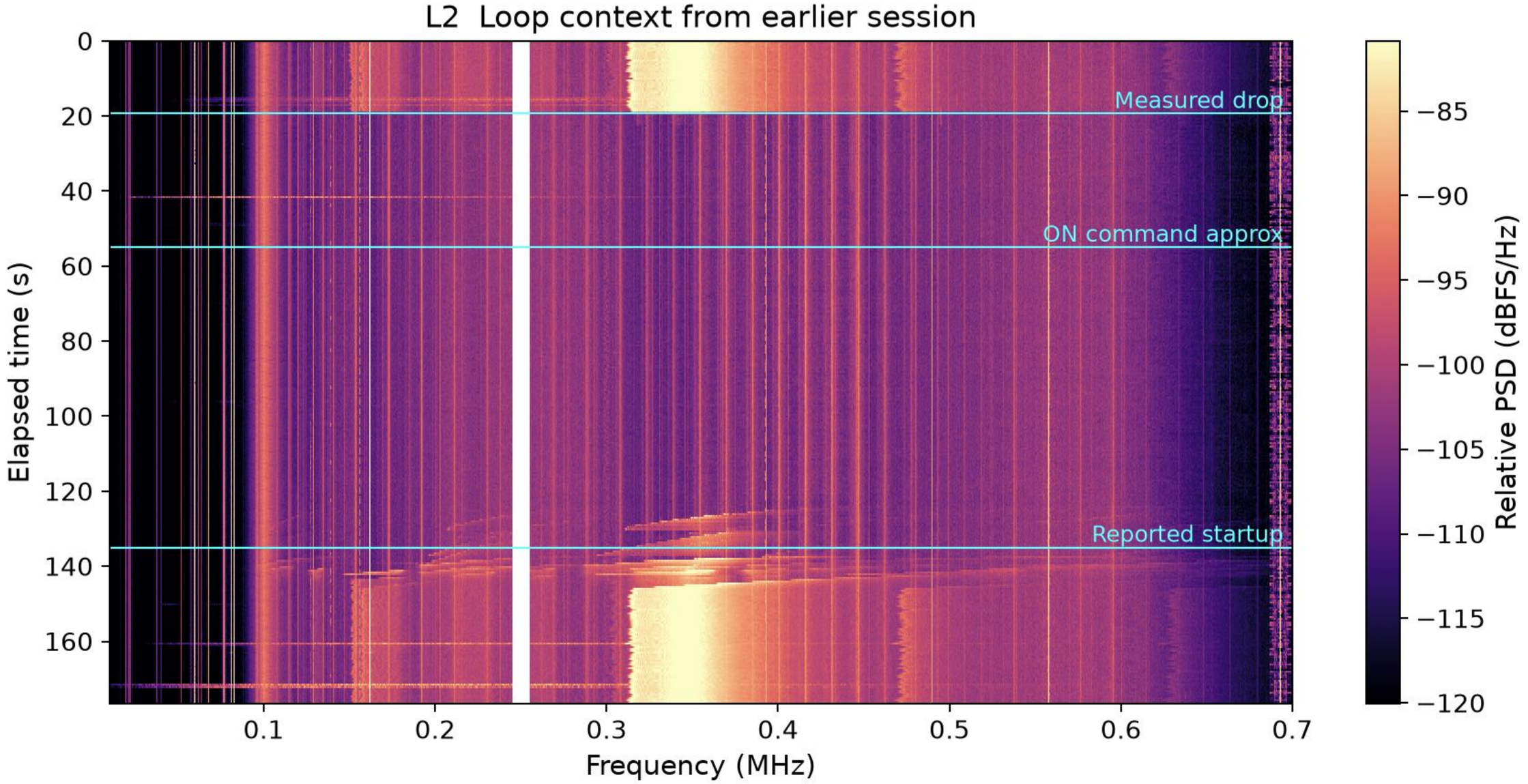


ON OFF ON shows RFI from panels

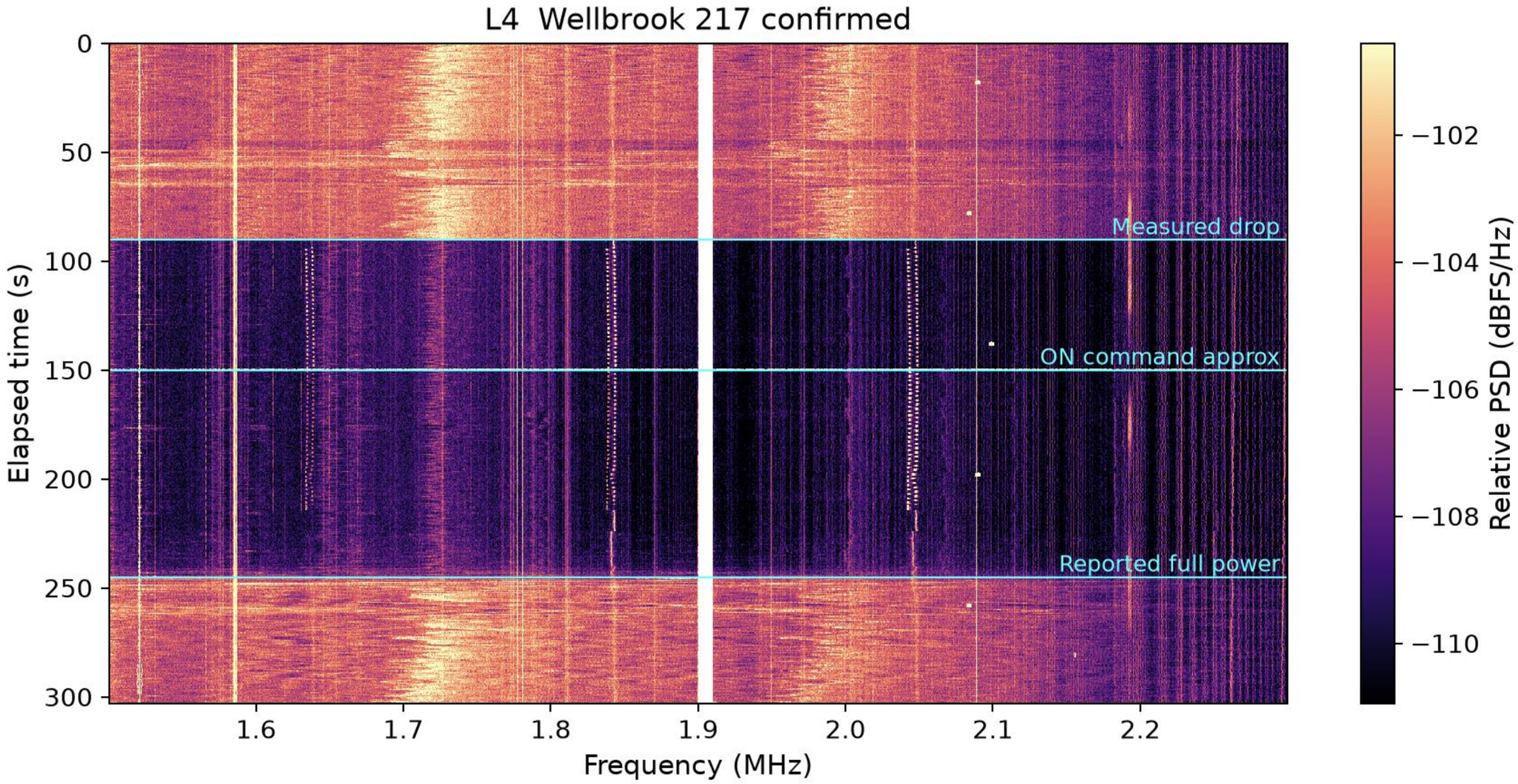
Note delayed startup after switch on



Impact of ecoflow microinvertor on medium wave am bands

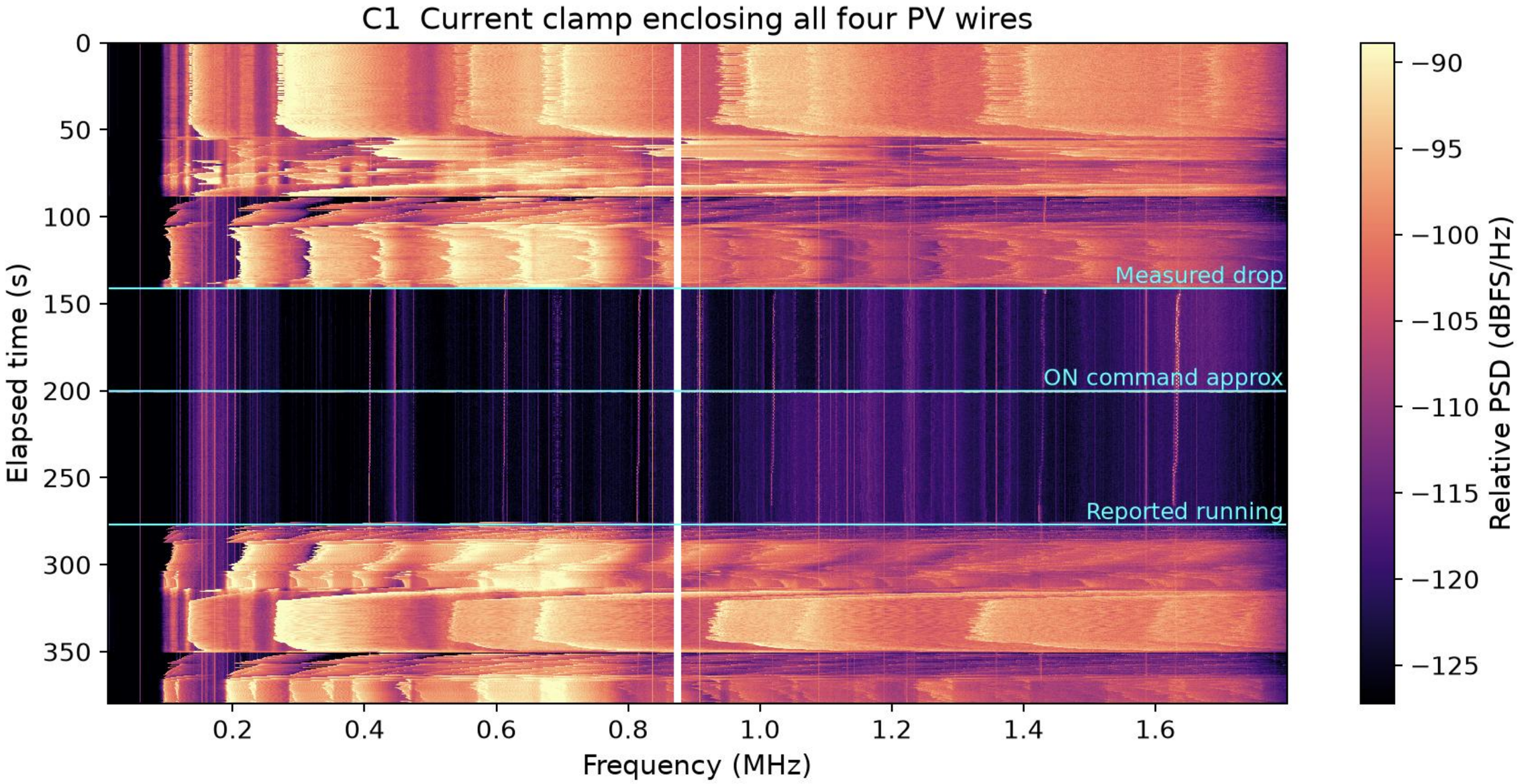


Impact of ecoflow microinverter on 160m

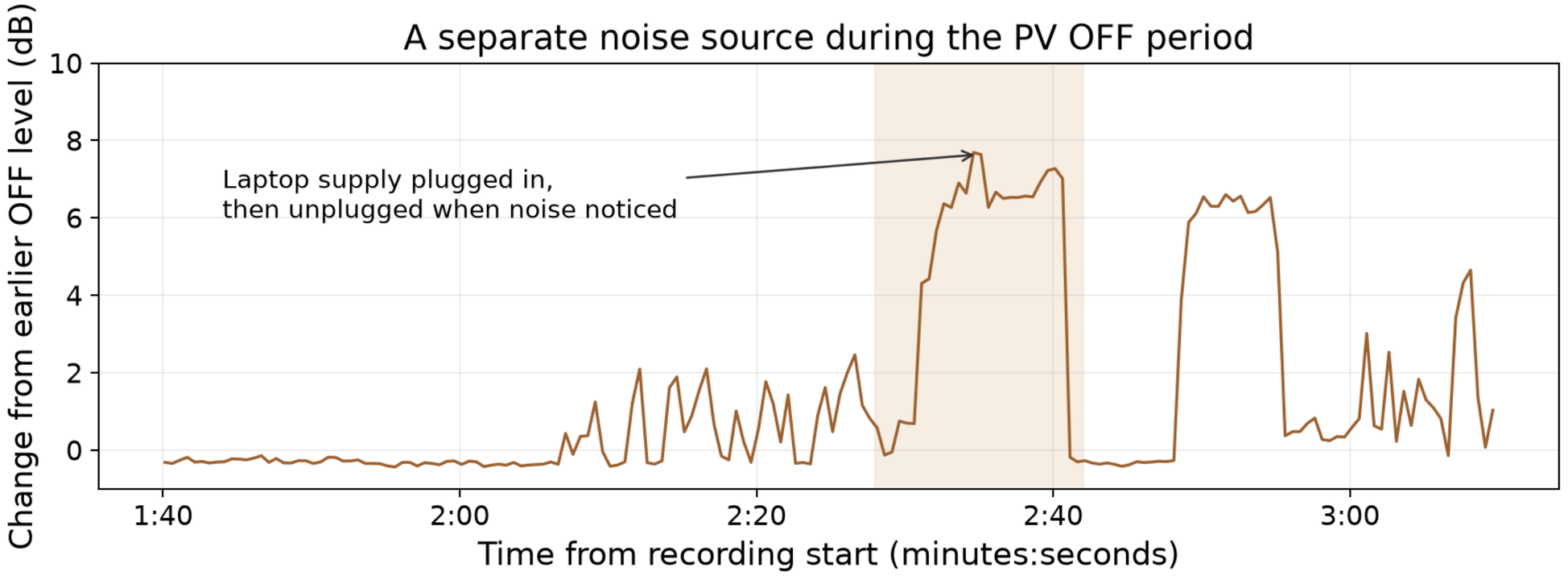


No interference to station antennas 50 to 60m away

Conducted RFI from PV wiring ecoflow balcony solar panel



Practical session assembling testing and using your E & H field probes



Beware of nearby sources corrupting recordings

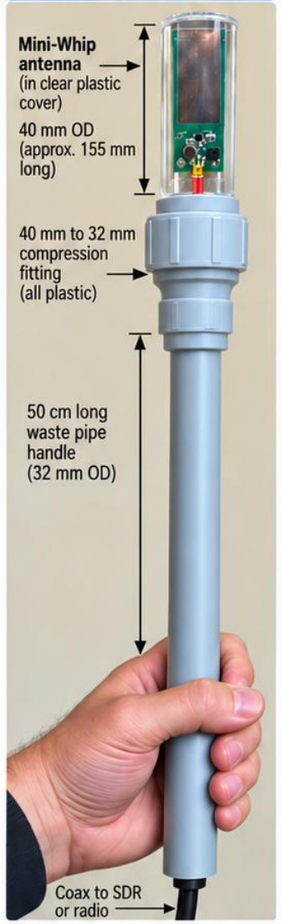
In this case the laptop power supply in perion when solar off

Confirme cause by you guessed it the ON OFF ON test

Handheld Mini-Whip Interference-Finding Probe

Using 40 mm to 32 mm compression fitting (all-plastic, no metal near antenna)

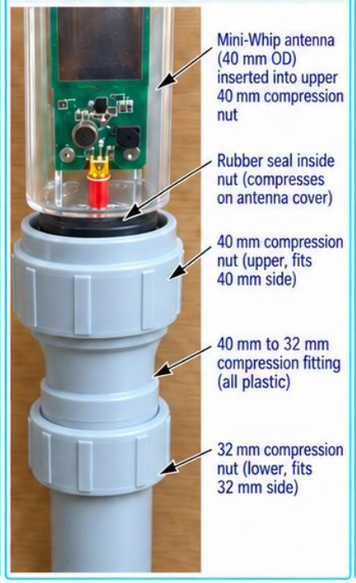
Assembled probe (full view)



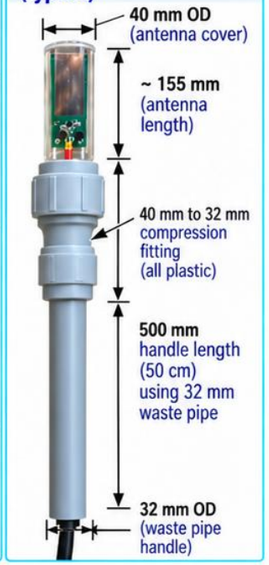
Exploded parts view



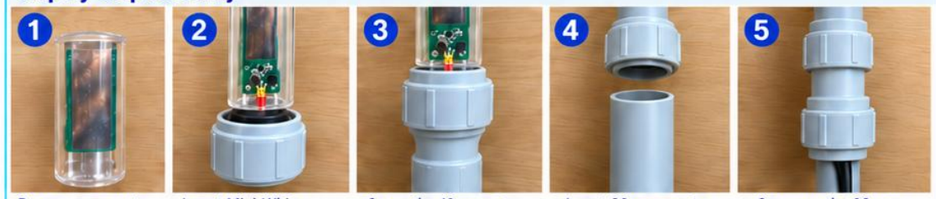
Top connection detail (close-up)



Key dimensions (typical)



Step-by-step assembly



1. Prepare your parts. Ensure fitting, seals and pipe are clean and free of dirt.
2. Insert Mini-Whip antenna into upper 40 mm compression nut (with rubber seal).
3. Screw the 40 mm nut onto the 40 mm to 32 mm fitting and tighten finger-tight only.
4. Insert 32 mm waste pipe into lower 32 mm compression end (with rubber seal).
5. Screw on the 32 mm compression nut and tighten finger-tight. Route coax out the bottom.

Important tips

- Keep metal away from the antenna end (at least 20 – 30 cm).
- Keep your hand at least 20 – 30 cm below the antenna.
- Use all-plastic parts (fitting, pipe, seals).
- 40 mm to 32 mm compression fitting suits the 40 mm antenna cover.
- Use 32 mm waste pipe for the handle, cut to 50 cm (or to a comfortable length).
- Ensure seals are fitted correctly.
- Finger-tight only – do not overtighten.
- Secure the cable and add strain relief at the bottom.
- For interference hunting, move slowly and look for relative signal strength changes.

Avoid

- ✖ Do not use metal hose clips or screws near the antenna.
- ✖ Do not grip the antenna near the top.
- ✖ Do not make the handle too short.
- ✖ Do not use metal fittings or conductive materials.
- ✖ Do not overtighten (can crack the plastic or damage the antenna).
- ✖ Do not rely on absolute signal strength (use relative changes).

Parts used (example)



1. Mini-Whip antenna (clear plastic cover)
2. 40 mm to 32 mm compression fitting (all plastic)
3. 50 cm (or to length) 32 mm waste pipe
4. Coax cable (to SDR or radio)

A simple, effective, all-plastic handle for your Mini-Whip – using a 40 mm to 32 mm compression fitting and a 32 mm waste pipe handle, ideal for tracing interference sources around the home or garden.

E field RFI probe

The mini whip antenna is available as a kit from Amazon or Ali-express



Practical session assembling testing and using your E & H field probes

- Take care with E Field probe to connect RSP1B to side without bias T



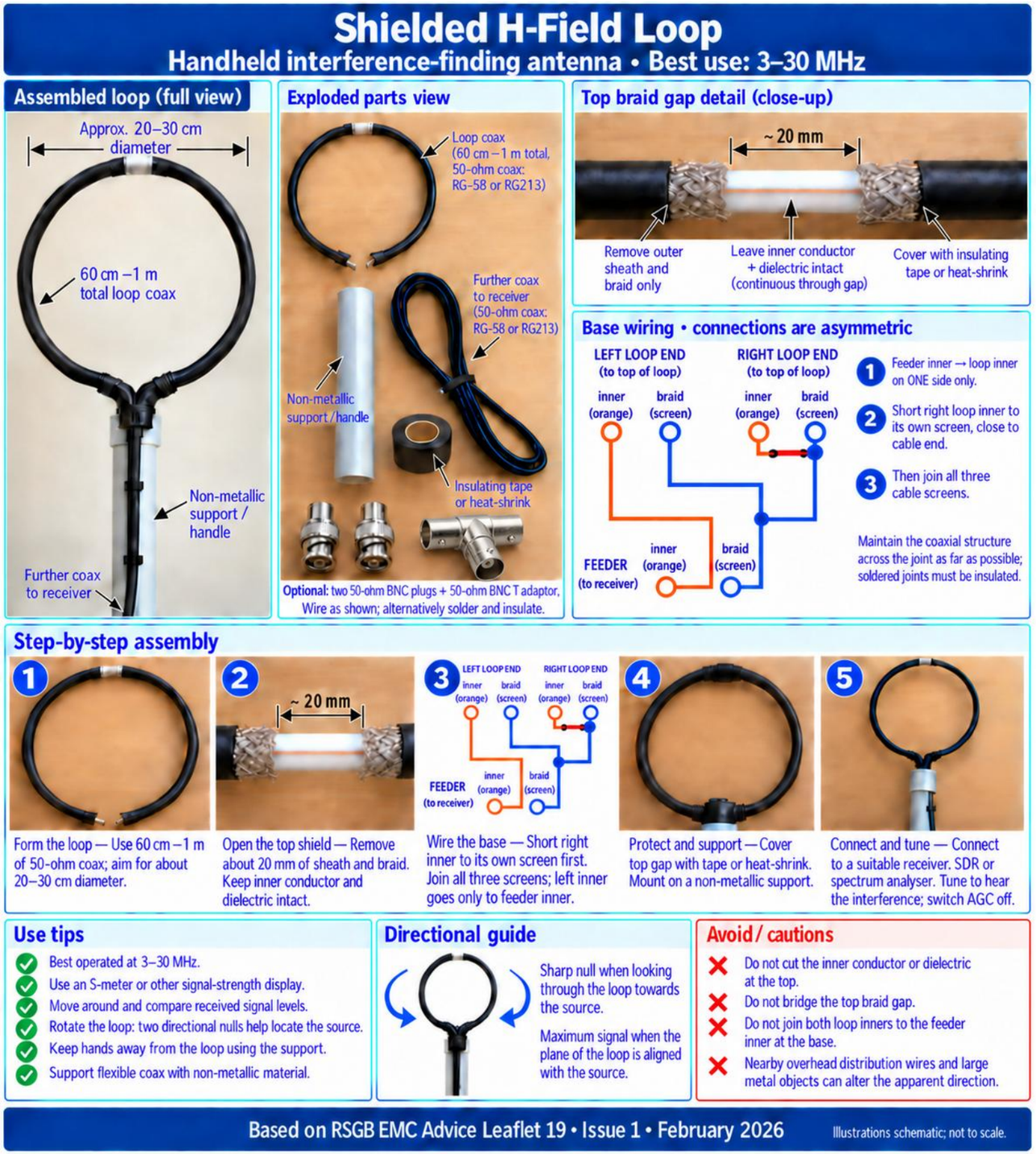


Connect antenna to opposite side to battery connector

Connect antenna to opposite side to battery connector

Insulating tape keeps it all together

Careful about metal case of RSP1B
Insulate bias T from case



H field directional loop

This can be used for locating direction of source by rotating the loop
Having found the direction along the line of the loop turn through 90 degrees and refine direction with null
Null is much sharper than peak

You can also use the loop to close in on source of RFI by moving in direction of increasing signal with loop aligned with source direction found above

H field probe



EMC leaflet 19 describes how to make it

Much less sensitive

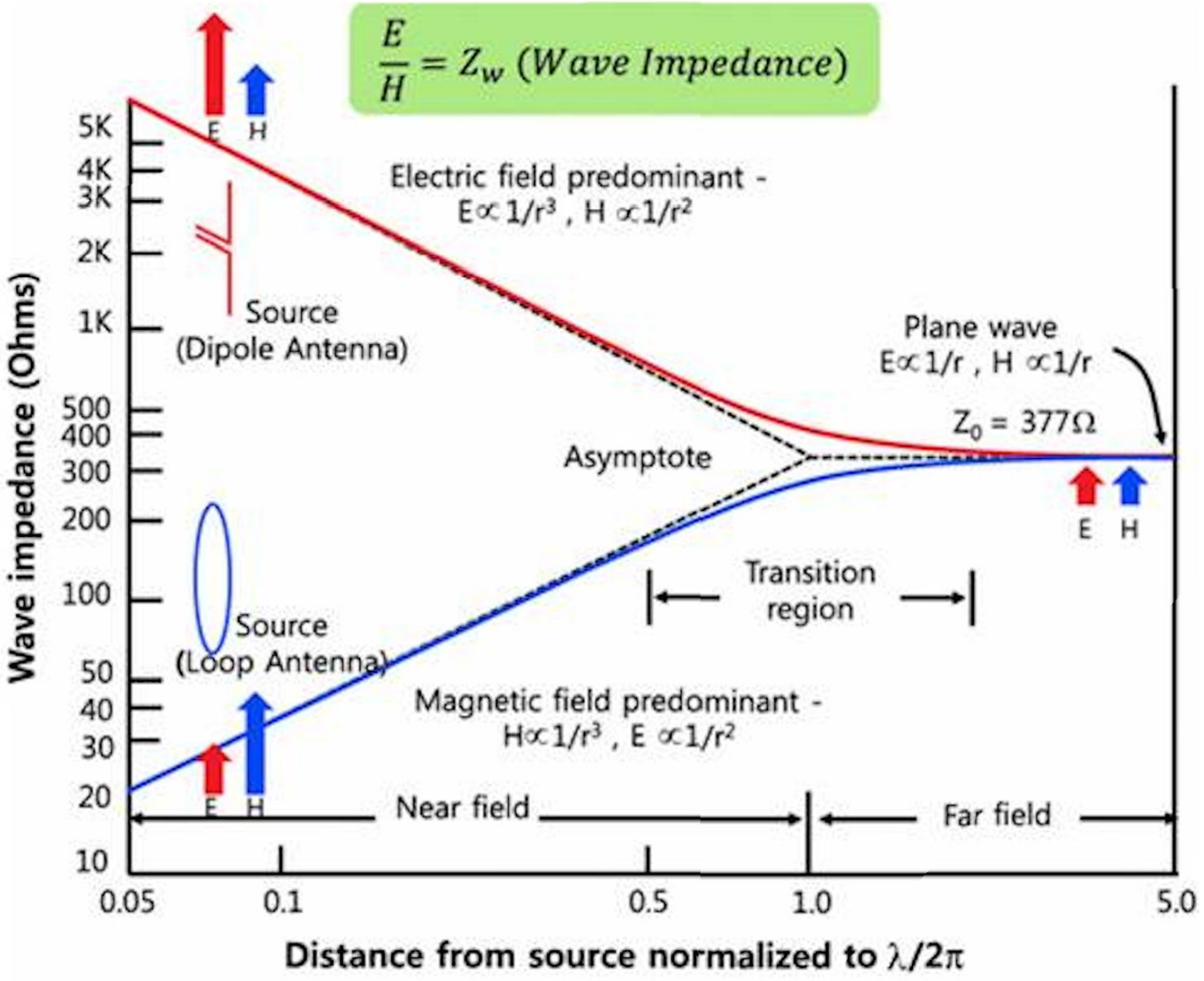
Advantage of DF’ing

Ideally would add a preamp for distant RFI

Small barrel connector allows the long lead from E field probe to be used with H field probe

Don’t loose it

Problem with calculating E and H field from EIRP close to antenna



Close to antenna the predominant E or H field falls off rapidly (inverse cube of distance) and the wave impedance varies with distance from antenna

In the far field a plane wave forms with wave impedance of 377Ω. This allows E & H to be calculated from EIRP

Assuming 377Ω in the transition region will give a conservative estimate for E or H providing a minimum limit for separation is imposed

Once off detailed modelling is needed to prove that this minimum limit does not underestimate the field strengths

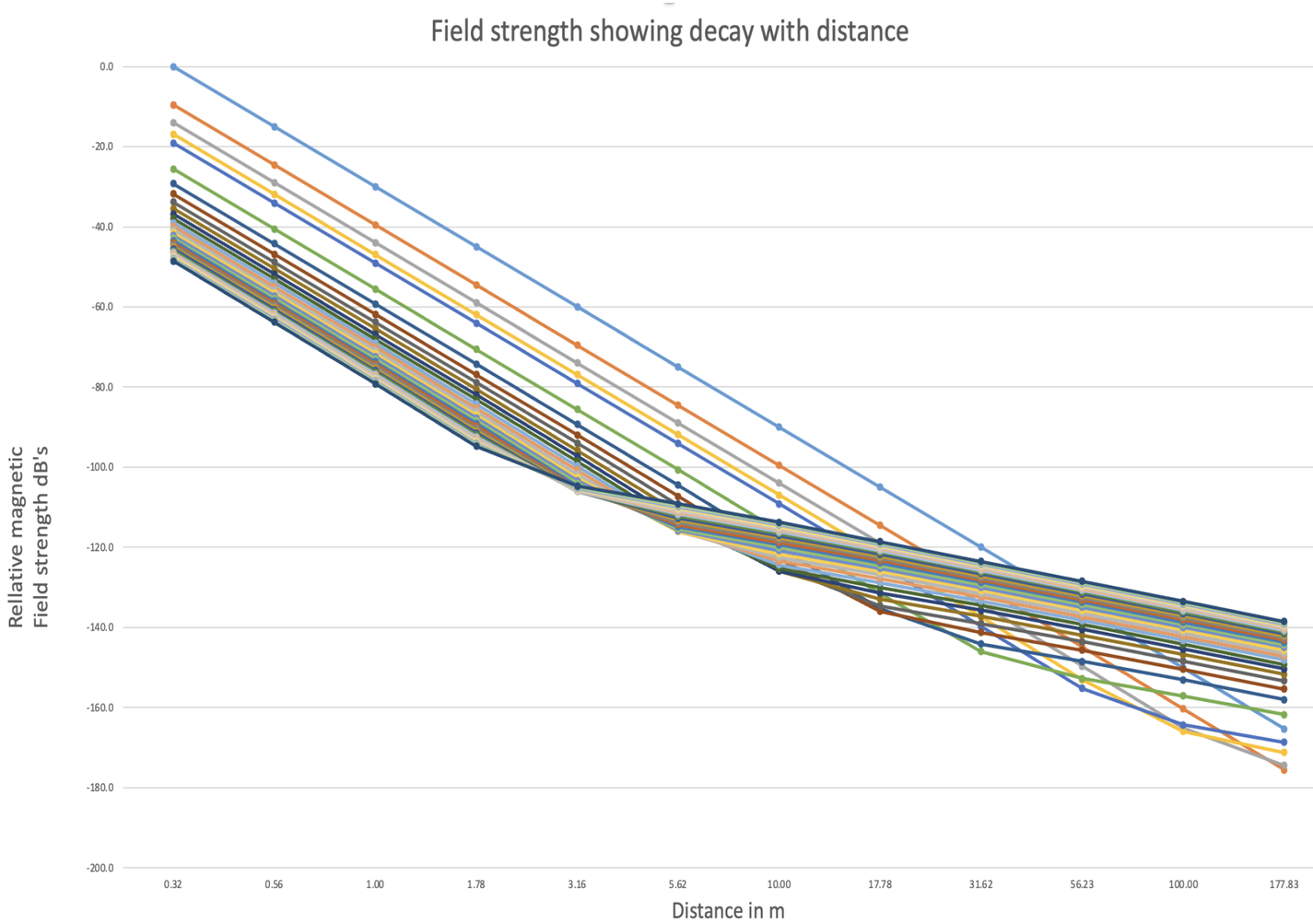
Problems with switching high currents

Induction hob, WPT EV, wind turbines, HVDC convertors

Higher harmonics decay slowly they predominate beyond 10 m

Multiple devices add up to exceed the specified level, but standards only consider a single device

IARU/DARC deploying ENAMs receivers to track trends in background noise levels (QRM)



Harmonics from 1 (75kHz) to 269 (20.18 MHz)

How to identify - Signatures

- Ensure SDR or receiver not overloaded eg by local MW stations
  - Beware of false signatures caused by artefacts, external filter if needed
  - Use attenuators - artefacts are not reduced real RFI is
  - Confirm with second receiver
  - Look for harmonics, 50 or 100Hz modulation, try to determine the background noise level
  - Use a loop antenna to improve rejection of other RFI sources
- Record or snapshot the RF spectra, waterfall, demodulated spectra
  - Compare these with signature templates, sigidwiki: RSGB and IARU are building RFI signature databases
  - Use signatures to confirm when source located

Finding RFI – Identify characteristics of RFI

- Know what your RFI looks like (spectra or waterfall) and sounds like
  - what frequencies it is on and what type of signal narrow or broadband, harmonic separations
- Turn off the power to your house
- Check with a different antenna to see if RFI reduces (E/H fields)
- Check a few hundred meters away in case it's a real transmission
- Log the times and strengths of the interference and correlate to electrical apparatus use
- Listen or use SDR to find the extent and nature of Interference see EMC04 – look for 50 or 100Hz modulation using AM

How to Locate Sources –Further away

- For distant sources try to DF, triangulate from another location
  - or use a mobile setup and get a helper to drive you around



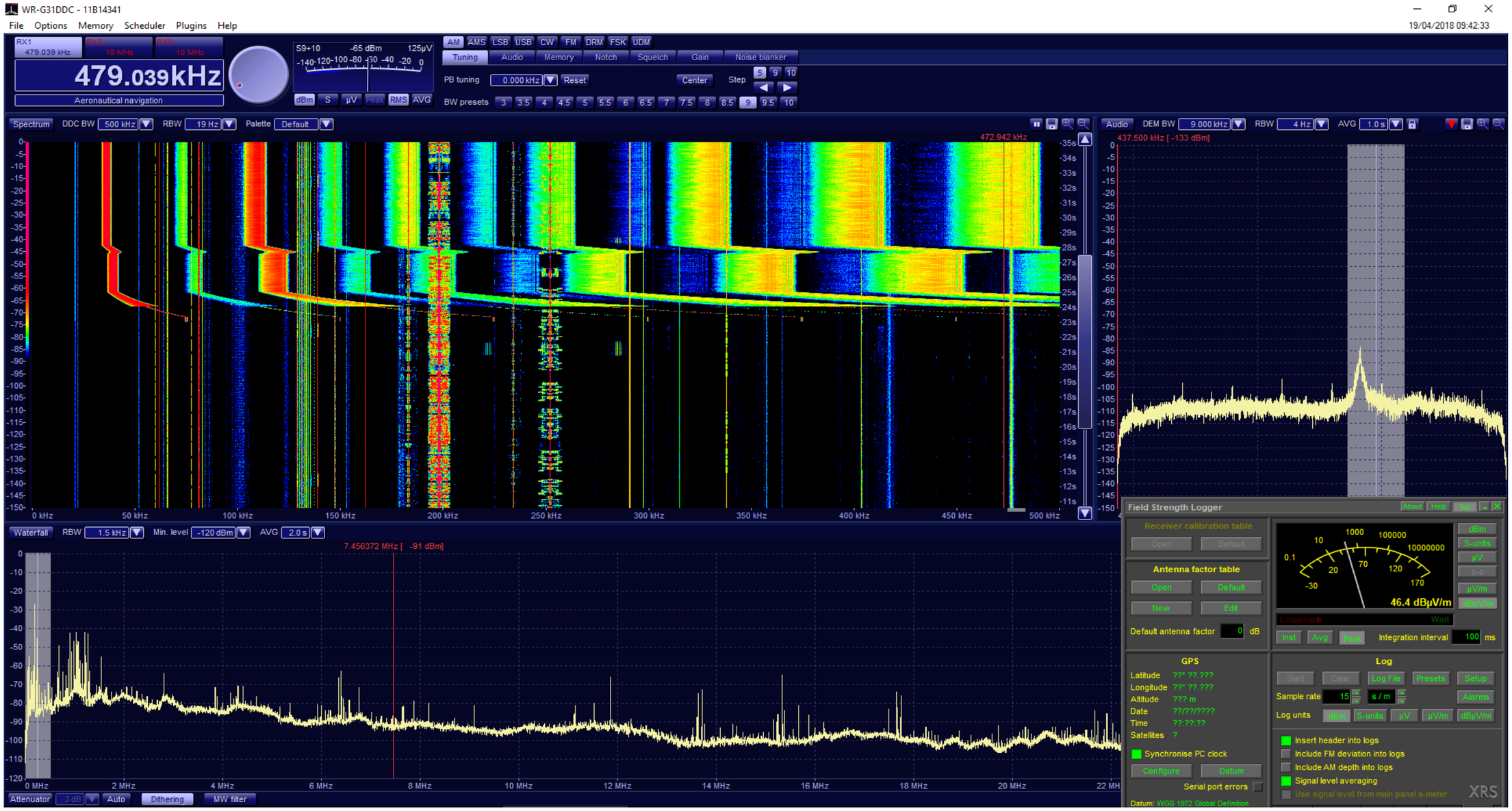


3.85 MHz

Field Strength Logger VDSL peak at 49dB(uV/m)



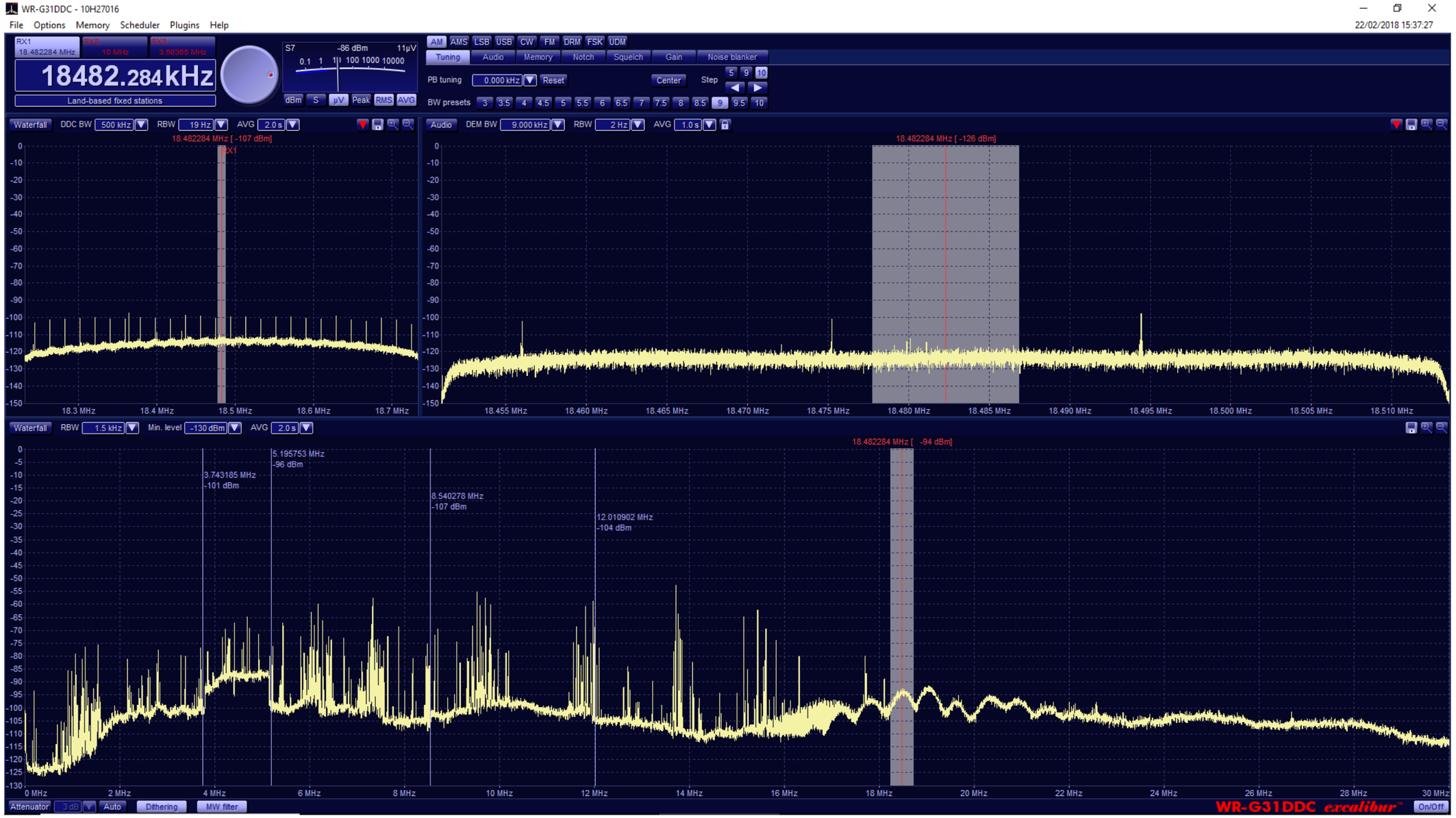
Induction hob on Field Strength Logger



theRSGB @theRSGB theRSGB YouTube /theRSGB

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What RFI can you see here?



Practical session finding RFI sources

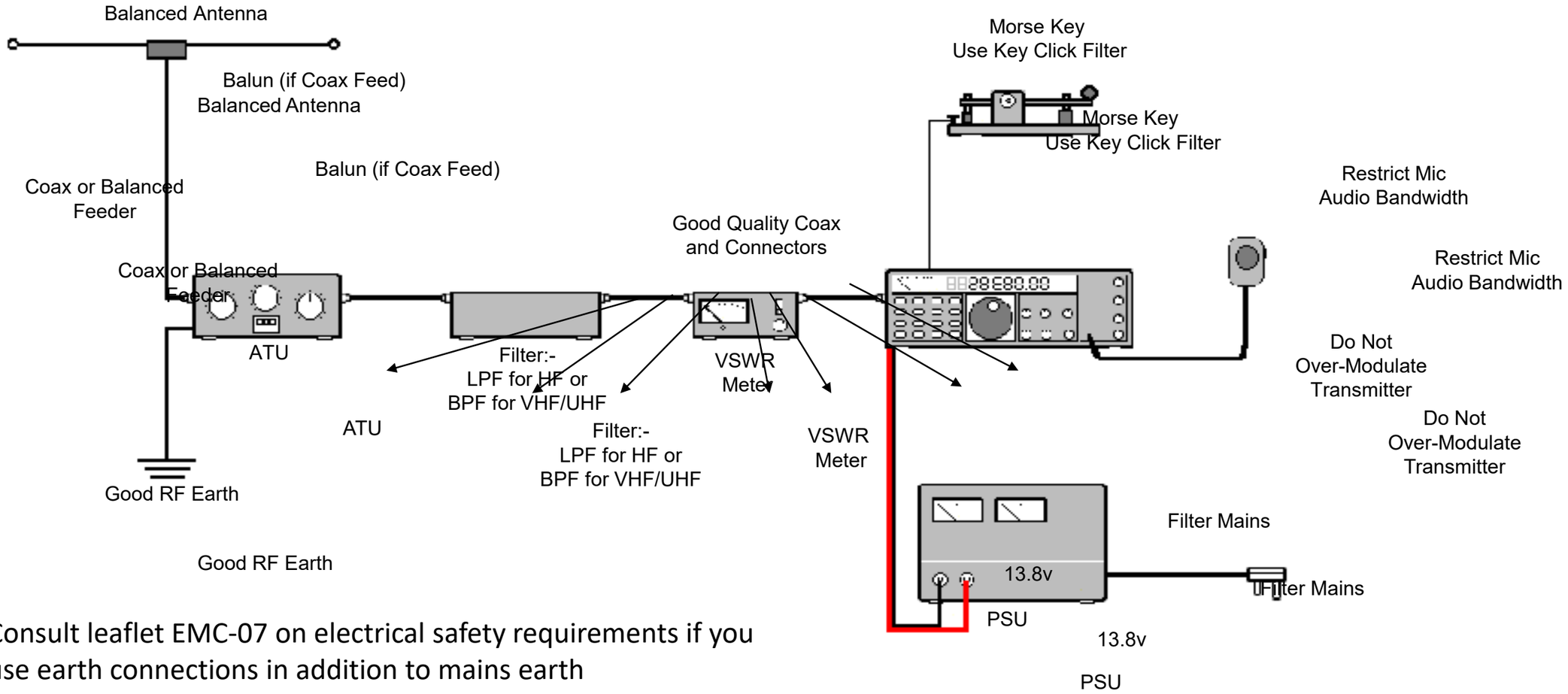




Students Build E and H field Probes

The finished articles – starwars to the rescue





Consult leaflet EMC-07 on electrical safety requirements if you use earth connections in addition to mains earth

Low inductance (wide –double sided PCB) ground bonding between units ground connectors, to stop RFI flowing on coax screens

Large choke (type 31 or 43) on mains and antenna coax

Earth antenna coax on entry to shack (static protection)

Bond equipment together

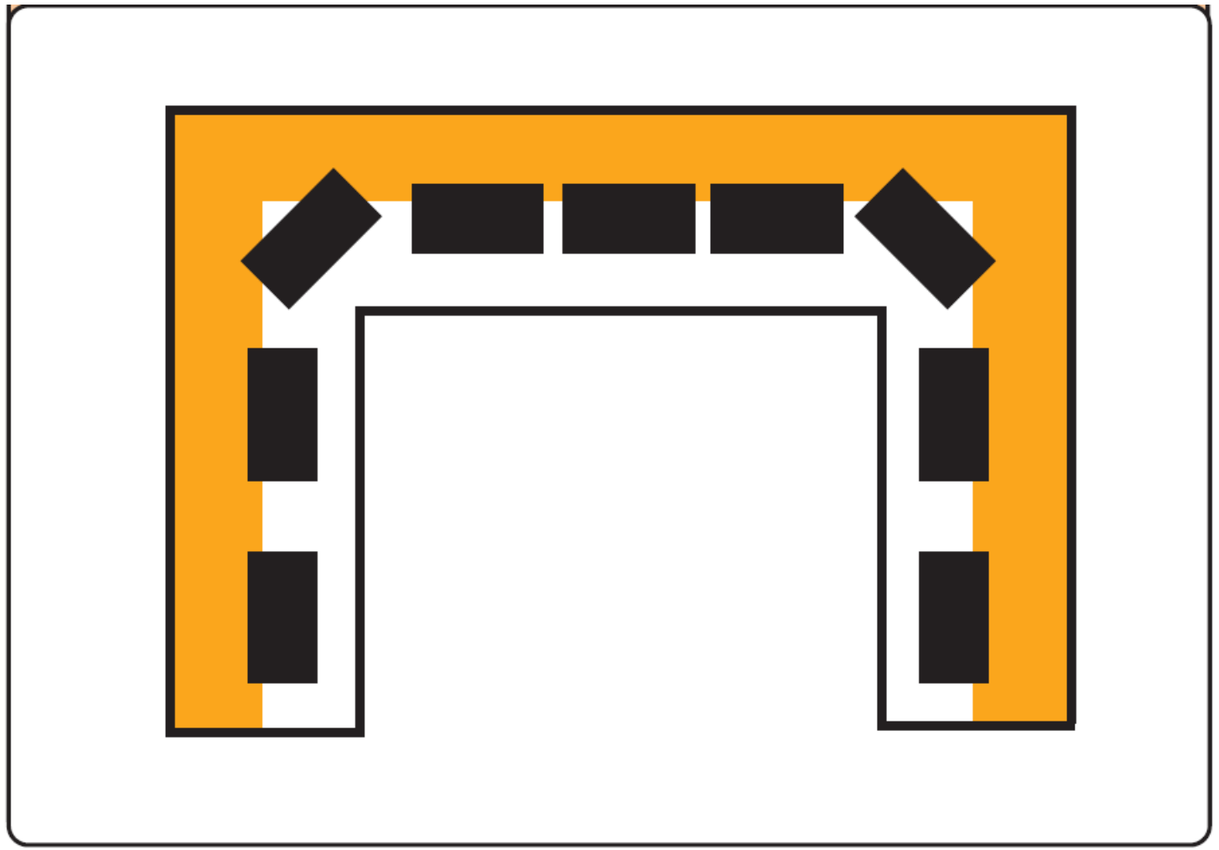


Consult leaflet EMC-07 on electrical safety requirements if you use earth connections in addition to mains earth

From GM3SEK

In-station RF Bonding

- **Best bonding method for RF**



Bonding by wide strips (eg PC board) for low inductance.

Very short links to the strip, from each piece of equipment

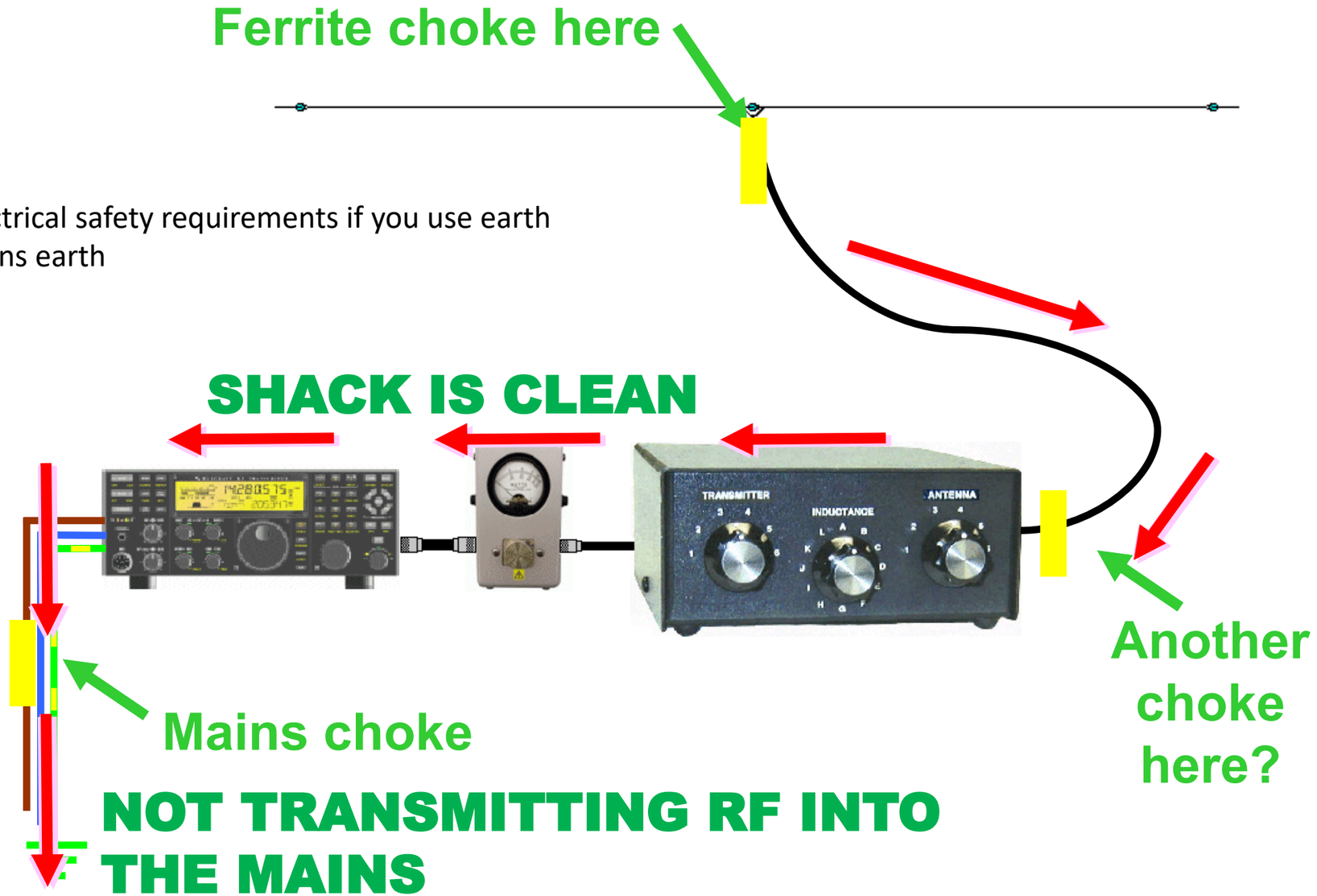
Then bond the strip to the filtered mains distribution board.

Consult leaflet EMC-07 on electrical safety requirements if you use earth connections in addition to mains earth

From GM3SEK

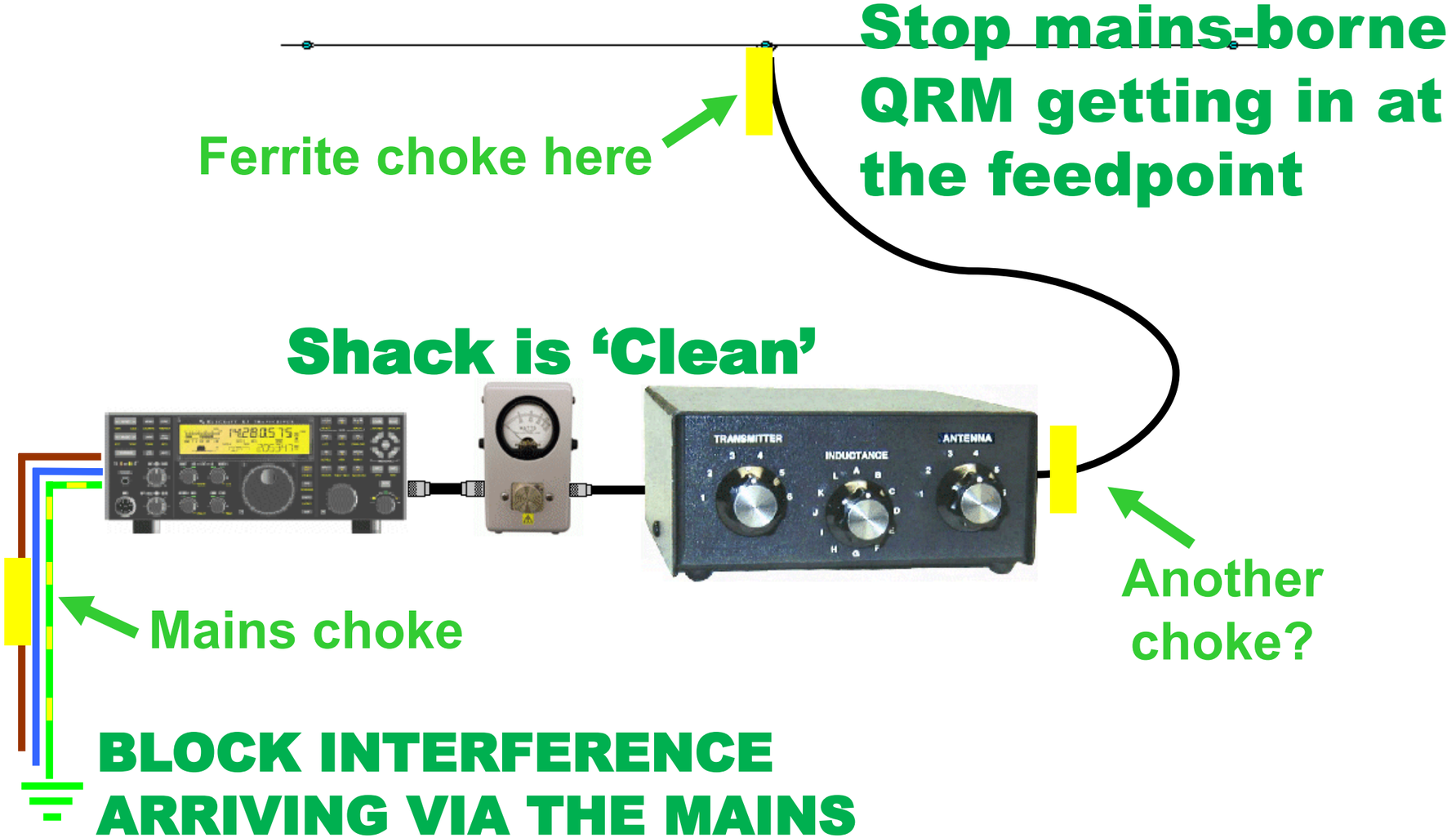
Clean up your transmissions

Consult leaflet EMC-07 on electrical safety requirements if you use earth connections in addition to mains earth



From GM3SEK

This will also improve your reception

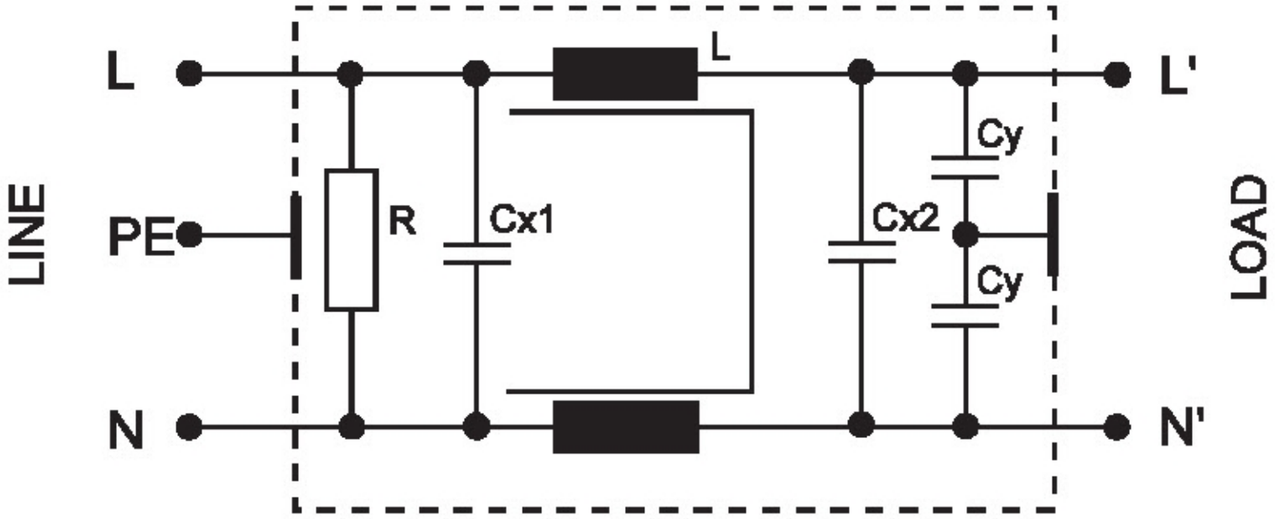


From GM3SEK

How to suppress conducted RFI

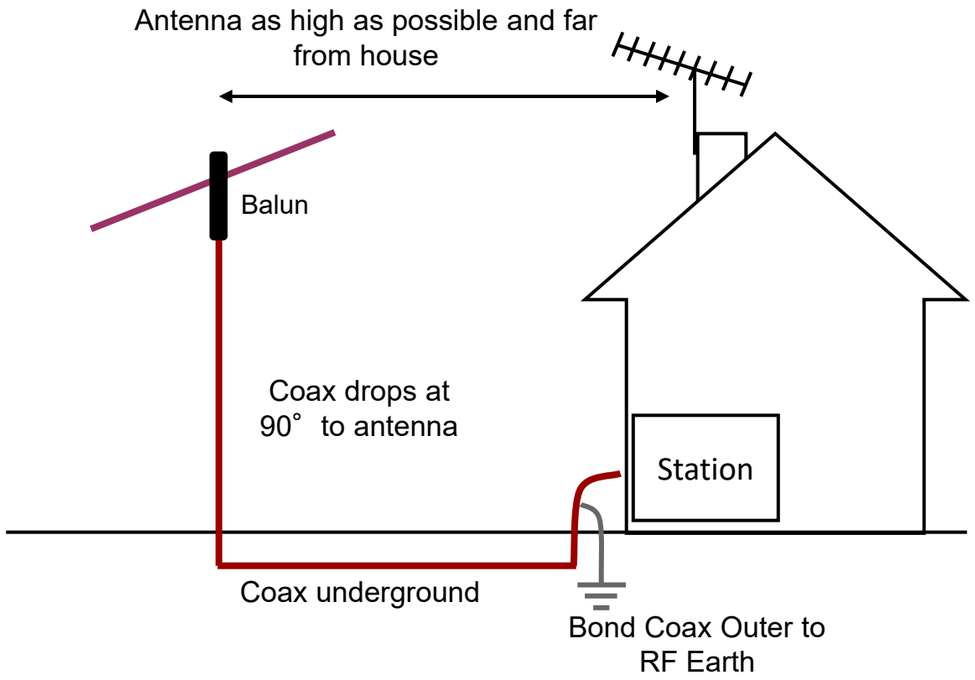
Either:

- provide a low impedance path to a good RF ground
- Or provide a high impedance for common mode signals
- Or do both in the form of an EMC Filter

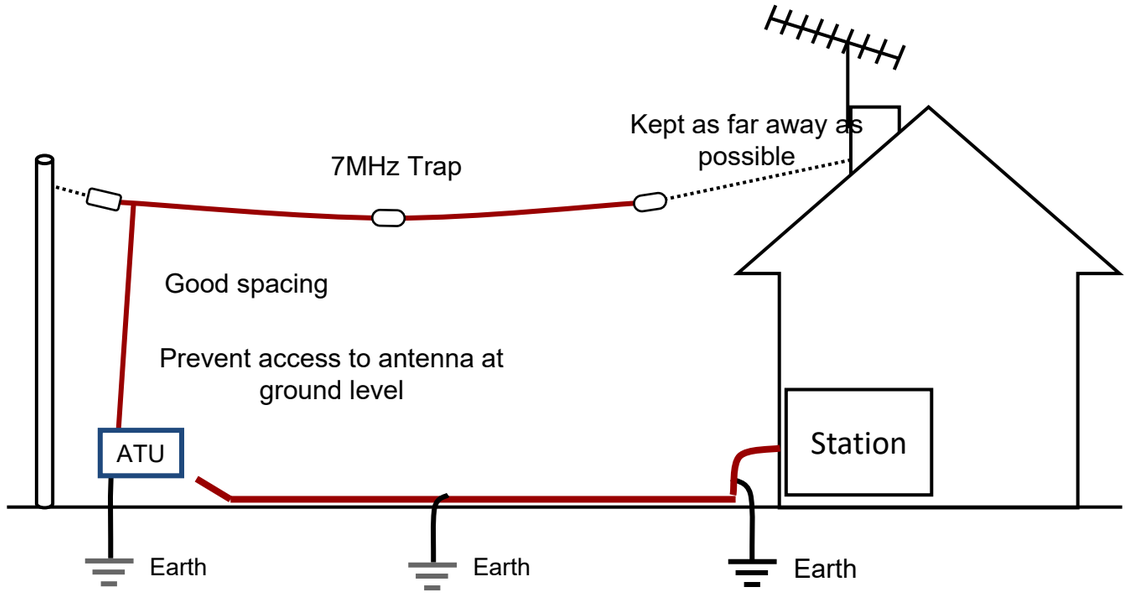


Typical Circuit Diagram

Setup to reduce RFI and breakthrough



Consider site of antenna
Filtering Mains
Length of RF earth
Turn off local sources eg ethernet
Suppress other sources



Use separate small loop
Rx antenna or a phasing box
to remove local sources

Practical Session

Using phase to cancel local noise

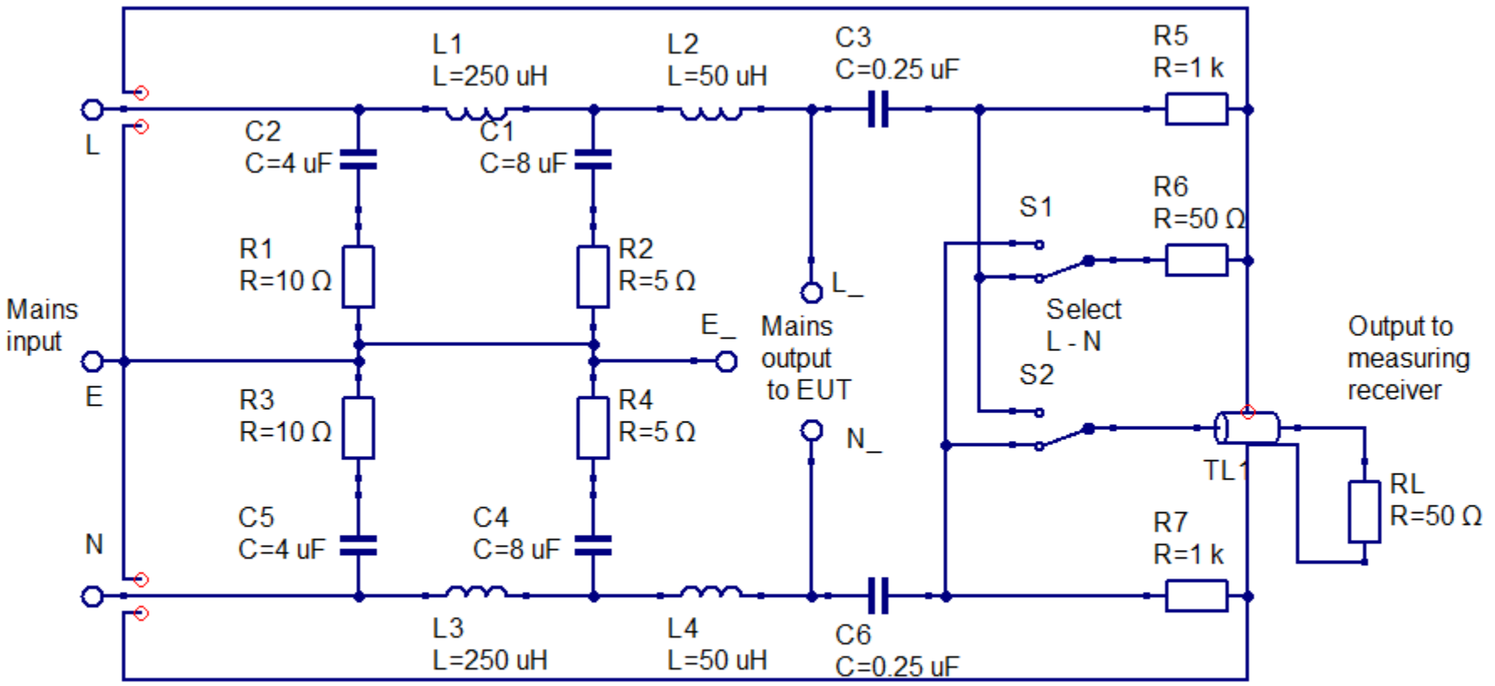
- Analog
- Digital

Use a separate antenna – active loop

Record I&Q for analysis of type

LISNs for Conducted Emission measurements (1)

- A Line Impedance Stabilisation Network (LISN) or Artificial Mains Network (AMN).
- Defined in CISPR 16 (EN 55016-1-2)
- This one is a V-network covering 9 kHz – 30 MHz
- EUT is Equipment Under Test

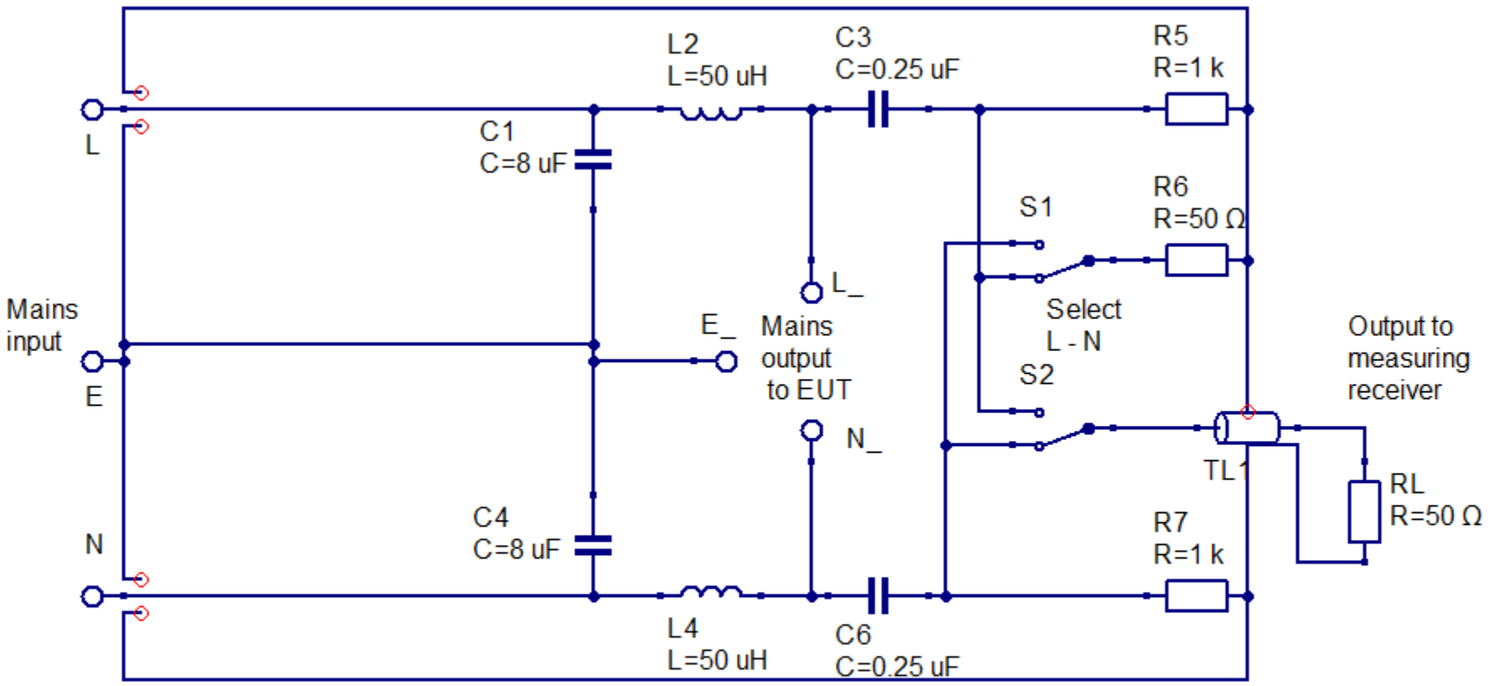


Artifical Mains Network (AMN) 50Ω/50µH + 5 Ω V-network
for 9kHz - 30 MHz as per EN 55016-1-2 Figure 5
Note high earth leakage current - don't try this at home!

Schematic created using uSimmics by Michael Margraf DD6UM
uSimmics – A Free and Powerful Circuit Simulator
(formerly known as QucsStudio)
https://qucsstudio.de

LISNs for Conducted Emission measurements (2)

- For a frequency range of 150 kHz – 30 MHz a simpler V-network can be used



Artifical Mains Network (AMN) 50Ω/50µH V-network
for 150kHz - 30 MHz as per EN 55016-1-2 Figure 6
Note high earth leakage current - don't try this at home!

Schematic created using uSimmics by Michael Margraf DD6UM
uSimmics – A Free and Powerful Circuit Simulator
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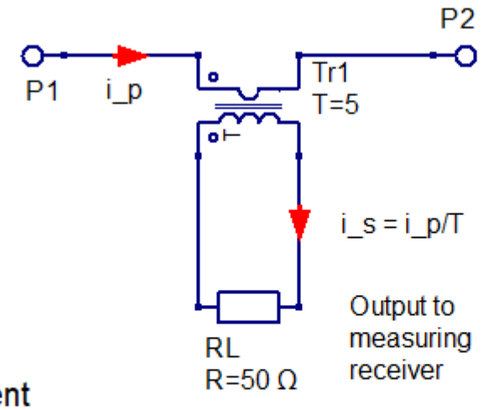
Current transformers for Conducted Emission measurements (1)

- Primary is the cable under test. Going straight through the split clip-on ferrite core is one ‘turn’.
- Ferrite is a type intended for EMC applications
- Secondary is 5 turns of insulated wire.
- A 50 ohm load and 5:1 turns ratio gives a 25:1 impedance ratio so it introduces a series impedance of only 0.5 ohms in theory.
- EN 55016-1-2 section 5.1.3 specifies a maximum of 1 Ω insertion impedance for a current probe
- Ideally, an electrostatic screen should be provided around the secondary winding to reduce unwanted capacitive coupling



Current transformers for Conducted Emission measurements (2)

- A current probe has a transfer impedance which relates the output to the current in the cable under test.
- $i_s = i_p/T$ where i_p is primary current, i_s is secondary current and T is turns ratio
- $v_L = i_s.R_L$ where v_L is p.d. across R_L
- Hence $V_L = i_p.R_L/T$
- If $T = 5$ and $R_L = 50$ then $V_L = 10.i_p$
- Calculated transfer impedance would be 10 Ω in this case.
- This can also be expressed in dB relative to 1 Ω as 20 dB (Ω)
- Subtract this value to convert dB(uV) in measuring receiver to dB(uA) in cable under test.
- Any clip-on ferrite core intended for EMC suppression should be suitable as a current transformer from approx. 1 – 30 MHz.
- The impedance of the secondary winding needs to be significantly more than 50 Ω over the range of operating frequencies so this limits the minimum usable frequency.
- The maximum usable frequency is determined by core loss and stray capacitance of winding
- The current transformer can be calibrated using a simple test jig with a VNA or a spectrum analyser with tracking generator.



RF Current transformer typically usable 1 - 30 MHz or more

Schematic created using uSimmics by Michael Margraf DD6UM
uSimmics – A Free and Powerful Circuit Simulator
(formerly known as QucsStudio)
https://qucsstudio.de

EMC filters and Chokes (1)

- Ferrite cores can be used to add impedance in series with a cable so as to reduce common-mode RFI.
- In many cases the cable is fitted with a connector so it cannot be threaded through a ring core and a split core is required.
- The key to success is to get enough impedance.
- A ‘figure of merit’ for a single ‘turn’ on a split ferrite core is the impedance at 10 MHz.
- The best available cores can provide 100 – 150 Ω at 10 MHz, some up to 190 Ω and some provide much less. A single turn is unlikely to provide much reduction.
- For a substantial reduction, e.g. 20 dB, aim for 1000 Ω at the frequencies of interest. This will require multiple turns or multiple cores.
- 2 turns give 4 times more impedance, 400 – 600 Ω - that might help
- 3 turns give 9 times more impedance, 900 – 1350 Ω - that should work quite well
- Multiple turns require a large enough core and enough spare cable but using multiple cores each with a single turn may need about 8 cores on each cable. These can be smaller cores but this can still be expensive.
- For frequencies below 10 MHz, e.g. 3.5 MHz, 5 MHz, 4 turns would be better if possible and multiple cores may be impractical.

EMC filters and Chokes (2)

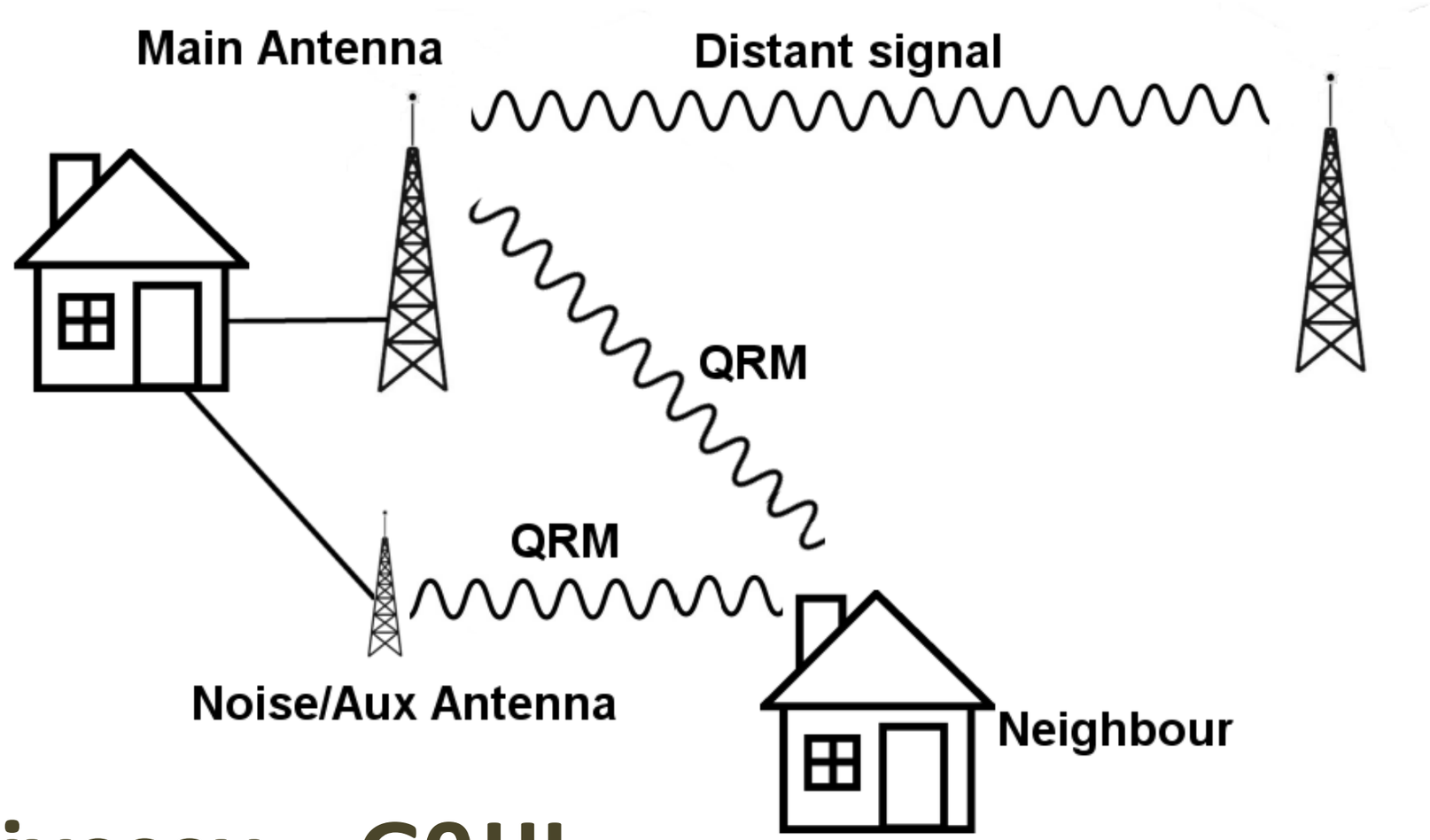
- Which cores to use and where to buy them:
  - Farnell Components
  - RS Components
- It is very important to select a suitable grade of ferrite – many cores are only effective at VHF/UHF so for HF you need something like:
  - Fair-Rite type 31 material
  - Kemet type HR1 material
- You may need cores with 25 – 30 mm diameter hole but be sure to use cores for round cables not oval.
- Split ferrite cores with oval holes and blue housing are available, e.g. 30 mm x 15 mm and these are designed for use on bus bars or in automotive applications. Some only give 20 Ω at 10 MHz so these are of little use for amateur radio purposes.

Practical session conducted and radiated noise sources



- Conducted emissions from Foxsur battery charger
- These have been extensively covered in RadCom EMC column
- Noise comb clearly visible on spectrum analyser

Interference Mitigation
– Phase Cancellation A typical situation

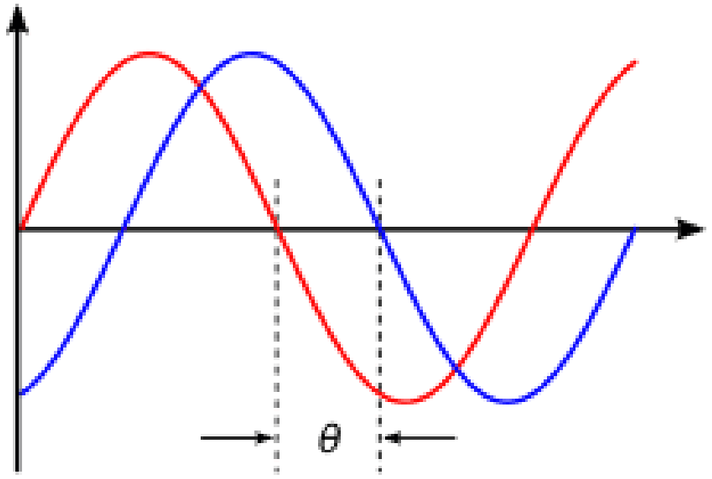


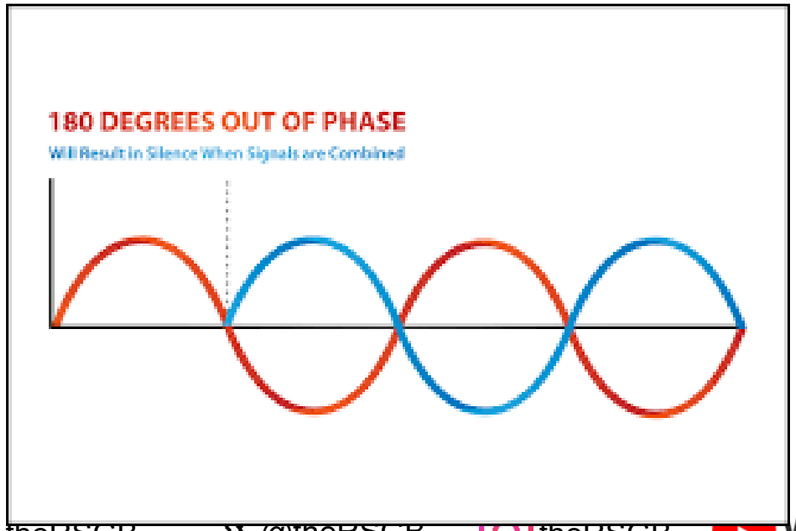
John Livesey – G0JJL

How does a phase cancellation device work?

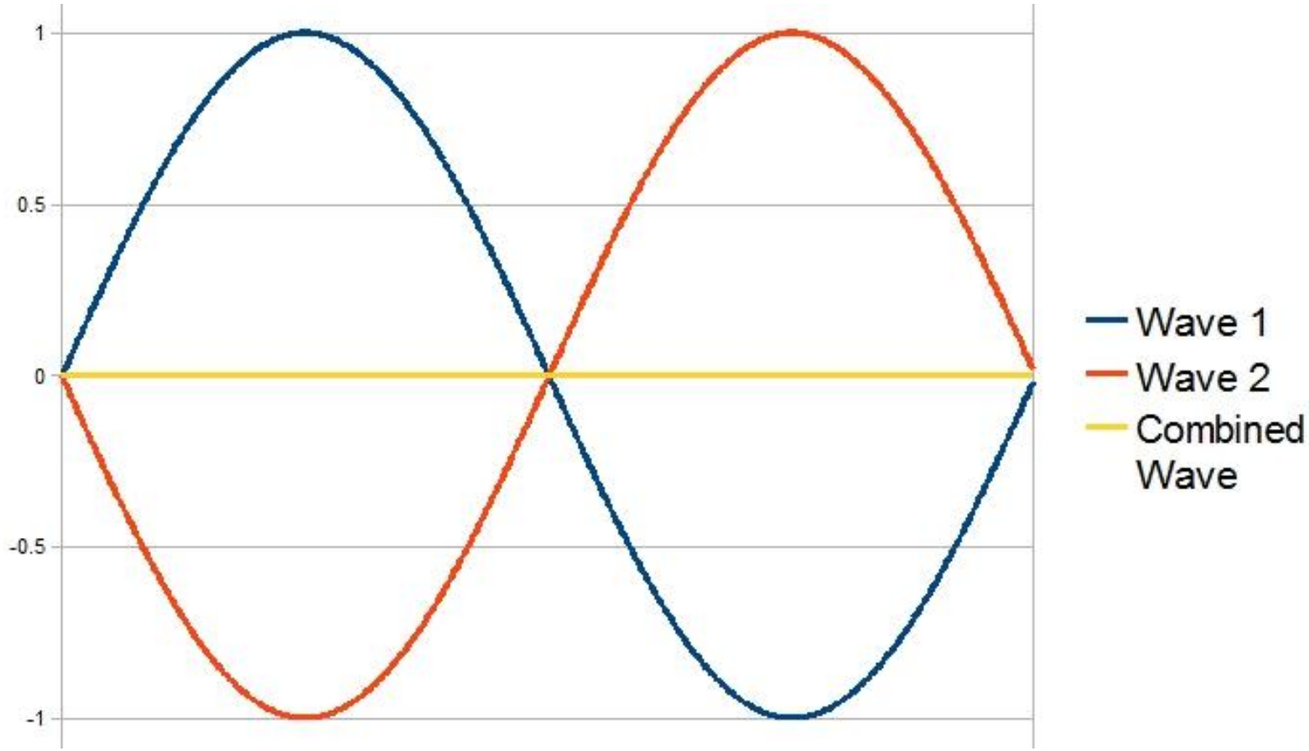
The canceller works by utilising the difference in phase between the wanted signal and the unwanted interference. If two receiving antennas are set up some distance apart and the same signal is received by both, then the phase relationship between the currents in the two antennas will depend on the direction from which the signal comes.

If the two outputs from the antennas are adjusted to be exactly the same in amplitude and exactly 180° out of phase, then if they are added together, they will cancel leaving almost no residual signal. The key to a practical canceller lies in the word 'exactly'. If the phase and amplitudes are not just right, most of the cancelling effect is lost.





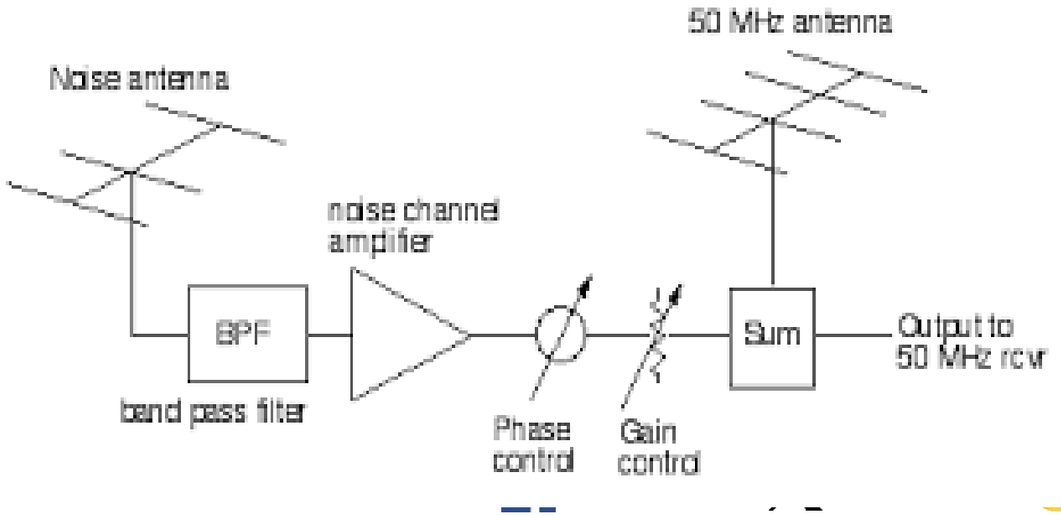
The ideal case resultant output – Yellow trace = 0



How is it achieved in practice?

In a simple interference canceller the gain and phase of the wanted and the unwanted signals from the noise (auxiliary) antenna are adjusted using two control knobs and added to the same signals from the main antenna until the unwanted signal is nulled out, leaving the wanted signal(s) more or less unaffected. How much the wanted signal(s) will be affected depends on the relative directions from which the wanted signal(s) and the interfering emission are coming, along with the distance between the two antennas.

As a rule of thumb, for interference coming from a fairly long way off (several wavelengths away), the antenna spacing should not be much less than one quarter-wave at the frequency of operation, though much smaller spacing can be used if some degradation of reception is acceptable. Where the interference source is much closer, the situation becomes very complicated, and it is simpler not to think in terms of antennas and nulls, but of picking up the interfering emission to use as a cancelling signal.



theRSGB YouTube /theRSGB
RSGB 2026 Convention

Popular phase cancellation devices









According to the National Association of Naysayers....

"They don't work"

"Too fiddley to set up"

"If the noise reduction features in this radio can't deal with it, nothing can"

"But you need to alter the settings if you change band"

"They cancel out everything not just the QRM"

"Too many extra connections needed"

A device in action – Judge it for yourself



A phase cancellation device being switched in and out of circuit to mitigate plasma TV interference in the 3.5MHz band

This demonstrates the typical level of mitigation achievable if the device is carefully adjusted and an efficient noise (auxiliary) antenna is used

Still not convinced?



Advantages

- Can mitigate or completely eliminate unwanted interference
- Easily adjusted if different sources of interference come and go over time
- Work on both narrow band and wide band sources of harmful interference over a large frequency range (LF to VHF)
- Provide a relatively low cost solution to harmful interference
- Enable continued spectrum access in high RF noise environments
- Easy to obtain, install and set-up (Kits or ready built units available)
- Low insertion loss
- Can be used to null co-channel user signals and not just harmful interference

Disadvantages

- Single units null only one source at a time (Multiple units can be cascaded – Additional cost)
- Require an efficient noise (auxiliary) antenna capable of providing sufficient signal levels into the unit
- On very rare occasions the wanted and unwanted signals are nulled out at the same time

Diversity Reception

Andy Carpenter, M6TMU

Agenda

- Defining “Diversity” in signal processing
- Maximum Ratio Combining – what is it?
- Understanding the challenge of noise and fading (low SNR)
- How diversity reception mathematically improves the signal-to-noise ratio (SNR)

Diversity

- Different types of Diversity
  - Frequency
  - Time
  - Spatial
- SDRs use Spatial Diversity + Signal Processing using coherence

MRC

- Maximum Ratio Combining is not new
- Weight the combined signals to maximise the overall SNR
- This is not selective diversity which picks the strongest single path
- Important – why you need coherence
    - Phase alignment (combats fading)
    - Amplitude scaling (maximises SNR)

Noise and Fading

- Different types of Diversity
  - Frequency
  - Time
  - Spatial
- Directly combats fading
- Does not eliminate noise, but can significantly reduce the impact of noise
- Uncorrelated noise does not add like weighted correlated signals do, so improved S over N (SNR)

Diversity Maths

- Channel Estimation
  - Using the phase relationship between the two tuners to calculate the channel ”response”
- Weight Calculation
  - Calculated based on channel gain
- Combining
  - Multiply and then summed up

Find out more…

sdrplay.com

andy.carpenter@sdrplay.com

facebook.com/sdrplay

x.com/sdrplay

www.rsgb.org



Requesting Ofcom Assistance



They can help you if you follow simple guidelines

Some myths to be aware of

Remember they will ask to see your EMF assessments

John G0JJL

Website Advice

- Is the interference real?

First determine whether the interference is real, and is actually coming from the outside world, or whether the apparent interference is really being generated within the receiver itself

- Is the source of the interference in your own shack or in your house?

Because interference is more likely to be acute the nearer the source is to the receiver and its antenna, a very good starting point to look for an interference source is within the shack itself or within the amateur's own house

- Is the interference coming from somewhere nearby your property?

If the source is not within your own location, could it be coming from a neighbour's house or a nearby location?

- Is the interference coming from a more distant source?

If other amateurs can hear the same interference then it is probable that a more distant interference source is involved

- Characteristics of the interference

If the source of the interference is not obvious, or if there appears to be more than one source, then examining the characteristics of the interference may help identify the possible cause(s)

EMC Helpdesk

EMC Advice Leaflet EMC 18
Guide for reporting harmful interference to Ofcom
This guide outlines the steps to report harmful interference to Ofcom for investigation Ofcom does not charge for this service, except in specific cases as outlined below. The later section in this guide provides an example of the type of wording to use when contacting Ofcom to request an investigation. Once Ofcom responds, you will need to agree some basic terms and conditions, which will include accepting any charges for their services as detailed below.

We recommend that you email your report to Ofcom using the following address: interference.report@ofcom.org.uk

https://rsgb.org/main/files/2025/10/EMC-Leaflet-18-Reporting-harmful-interference-to-Ofcom-v1.2.pdf

Harmful interference as defined

- Section 115 Wireless Telegraphy Act 2006
- (4) Interference with any wireless telegraphy is not to be regarded as undue for the purposes of this Act unless it is also harmful.
- (5) For the purposes of this Act interference is harmful if—
- (a) it creates dangers, or risks of danger, in relation to the functioning of any service provided by means of wireless telegraphy for the purposes of navigation or otherwise for safety purposes; or
- (b) it degrades, obstructs or repeatedly interrupts anything which is being broadcast or otherwise transmitted—
- (I) by means of wireless telegraphy; and
- (ii) in accordance with a wireless telegraphy licence, regulations under section 8(3) or a grant of recognised spectrum access or otherwise lawfully.

Keep it concise and focused



Some myths to be aware off

- <u>EMC Leaflet 18 – Reporting harmful interference to Ofcom</u>

Any questions?



Find out more…

rsgb.org/emc and rsgb.org/emf

emc.chairman@rsgb.org.uk

www.rsgb.org

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