The Effect and Mitigation of Vineyard Trellising on EM38 Soil Conductivity Measurements

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Abstract

The EM38 has a widely accepted role in precision agriculture for the efficient mapping of sub-surface apparent electrical conductivity at data densities of the order of 10 m. The resultant high-resolution maps of apparent conductivity enable agriculturists to infer soil properties such as soil moisture and salinity which aid localized crop management decisions. However, when applied to viticulture, previously published research has confirmed that the use of electromagnetic induction instruments, such as the EM38, has been flawed by the interference from the conducting wire and steel-post loops of the grapevine trellising. This has raised questions about the reliability of interpretations made from potentially flawed maps of apparent conductivity in vineyards.

In this research, a combination of component and whole trellis assembly trials confirmed that this interference was separable into two significant components: the steel trellis loops and the trellis-earth system. Furthermore, while these two effects theoretically interact, the contributions from each were found to be conceptually separable in terms of both the EM38 response and possible mitigation or data correction strategies.

An analytical expression was initially developed to predict the interference from steel conducting loops in terms of the mutual inductance from both the transmit and receive coils of the instrument to the Target Loop, the loop's self-inductance, and its electrical resistance. Increasing the complexity of the loops to reflect real trellis geometries necessitated the use of a numerical analysis program (FastHenry) to calculate the parameters of loop resistance, self-, and mutual-inductance, for substitution into the analytical expression.

Several patterns within the trellis interference were discovered in the simulated vineyard trellising and the commercial vineyard tested. These patterns led to several mitigation/correction possibilities. Future work in the trellis interference on EM38 surveys should focus on the development and refinement of the practical empirical mitigation strategies proposed, rather than further analyses of the detailed mechanism of the trellis-loop and trellis-earth eddy currents because of the difficult to predict post-wire and post-earth resistances, as well as the complexities of the trellis-earth eddy currents.

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Abbreviations, Acronyms, Symbols and Conventions

Variable, Unit or *Symbol*	**Definition or Meaning**	**Units**
α	Shape parameter (aspect ratio for rectangles)	Unit-less
a	Electrode spacing	m
A	Area	m^2
A	Amperes	Amperes
B	Magnetic flux density (magnetic induction, vector quantity)	$T \equiv kgs^{-2}A^{-1}$
cm	Centimetres	10^{-2} m
σ	Electrical Conductivity (≡EC)	S≡Siemens
Δ	Delta (implies change in value of)	Not applic.
d	Incremental change	Not applic.
EC_a	Apparent Electrical Conductivity	S≡Siemens
EC_e	Electrical Conductivity of Extracted soil sample	S≡Siemens
ER	Soil Electrical Resistivity	Ω-m
ϕ	Depth response function	Not applic.
Φ	Magnetic flux	$Vs \equiv kgm^2s^{-2}A^{-1}$
f	Frequency	s^{-1}
H	Magnetic field (vector)	Am^{-1}
Hr	Hour	s
H_s	Secondary magnetic field (vector)	Am^{-1}
H_0	Primary magnetic field from Loop 0 (vector)	Am^{-1}
i	Imaginary part of a complex number ($i^2 \equiv -1$)	Unit-less
I	Current, electrical	A

I_Q	Current in Quadrature phase	A
Km	Kilometre	m
ℓ	Length of a cylinder	m
L	Self-inductance	$H \equiv VA^{-1} \equiv kgm^2s^{-2}A^{-2}$
L	Litre	m^3
μ	Magnetic permeability	$kgm^{-2}A^{-2}$
μ_0	Magnetic permeability in vacuum i.e. free space ($4\pi \times 10^{-7}$)	$kgm^{-2}A^{-2}$
μ_r	Relative magnetic permeability	dimensionless
m	Metres (but as a prefix means milli: 10^{-3})	m
m	Dipole moment (vector quantity)	Im^2
M	Mutual inductance	$H \equiv VA^{-1} \equiv kgm^2s^{-2}A^{-2}$
mm	Millimetres	m
N	Number of turns of a coil (of wire)	integer
π	Pi	constant
ρ	Resistivity (reciprocal of conductivity)	Ωm
R_H	Horizontal depth response function (cumulative)	Ωmm^{-1}
R_V	Vertical depth response function (cumulative)	Ωmm^{-1}
r_x	Cross-sectional radius	m
r	Loop radius	m
R	Resistance, electrical (Reciprocal of conductance)	Ω
R	Radial Vector	
s	Seconds	
s	Spacing or separation	m
s_1, s_2	Spacing or separation to Loop 1 and Loop 2 (respectively)	m

S	Siemens, a unit of conductance	$(\equiv \Omega^{-1})$
S	Surface	
t	Time	s
V	Voltage & EM38 Response value in Vertical dipole mode	
V	Volts	$JA^{-1}s^{-1}$
V_B	Background EM38 Response value (Vertical dipole mode)	
V_{BE}	Bare-Earth EM38 Response value (Vertical dipole mode)	
V_Q	Quadrature EM38 Response value (Vertical dipole mode)	
Ω	Ohms, unit of resistance, electrical	VA^{-1}
ξ	Electro-motive force	$V \equiv WA^{-1}$
ω	Angular frequency	s^{-1}
z	Depth	m
Z	Complex impedance, electrical	Ω

Acronym or Abbreviation	**Meaning**
BE	Bare-earth
CD	Coefficient of Determination, statistical
CW	Cordon Wire
conn.	Connected
corr.	Corrected
dGPS	Differential GPS
DW	Dripper Wire

EC	Electrical Conductivity
EMI	Electro-Magnetic Induction
F1	Foliage wire 1 (lower foliage wire)
F2	Foliage wire 2 (upper foliage wire)
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GRS	Gamma Ray Spectroscopy
GW	Grab Wire
insul.	Insulated
N	Northing
ppt	Parts per thousand
Rx	Receiver
TDR	Time Domain Reflectometry
Tx	Transmitter
UNE	The University of New England

Certificate of Originality

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

[redacted]

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Armidale,

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