Aesthetics and Electrical Characteristics of Guitar Pickups

Introduction

Electric guitars function by transmitting the 'sound' in the form of an electric signal into an amplifier to be amplified, processed and played through. The electric guitars do this by **picking up the vibrations of the strings and transferring them into a signal** through the guitar pickup.

The guitar pickup consists of magnetic cores with an enamelled (Thinly insulated) cable coiled around the magnetic cores. **Pickups are not manufactured identically and can therefore have different properties**. This can be done deliberately to achieve specific tones, for example, they can be designed to have a peak resonance (frequency at which the signal is the strongest) closer to desired frequencies for a better bass or treble.

The variation in manufacture is what I'm investigating on a practical level. Pickups can be modelled using virtual circuit simulation [2] to achieve specific performances yet visualisation and non ideal conditions are important in investigating the relationships. **The manufacture variation being explored is the quantity of turns in the coil and the wire thickness of the coil**. These vary electronic characteristics, increasing turns increases inductance and wire gauge varies resistance. Both important factors to consider when analysing data. Wire gauge being used is AWG standard (American wire gauge)

This project represents a part of a wider investigation on guitar pickups in collaboration with the Nottingham Trent University Music Engineering Laboratory.

Aims

The main aims are to investigate:

- The **relationship between the a) Quantity of turns b) wire gauge (thickness)** used and frequency response of the pickup. So the position of the peak in impedance for the ideal tonal response and the peak height of the resonance for the quality or 'Q' factor of the signal.
- The **effects of manufacturing errors** and to understand identification of broken equipment to analyse causation

Method

- Pickups were connected to a VersaSTAT 4 Potentiostat machine to have an array of varying AC voltages applied across the pickup. Thereby collecting data across the suitable frequencies (100 Hz to 22 KHz—Audible range)
- Raw data is collected through the machine's software studio (VersaSTUDIO)
- The experiment is repeated using differently manufactured pickup with either: a) different quantity of turns or b) different wire gauge.
- All the data is collected and exported into MATALB for post-processing graphs, visual analysis and data fitting.

Results

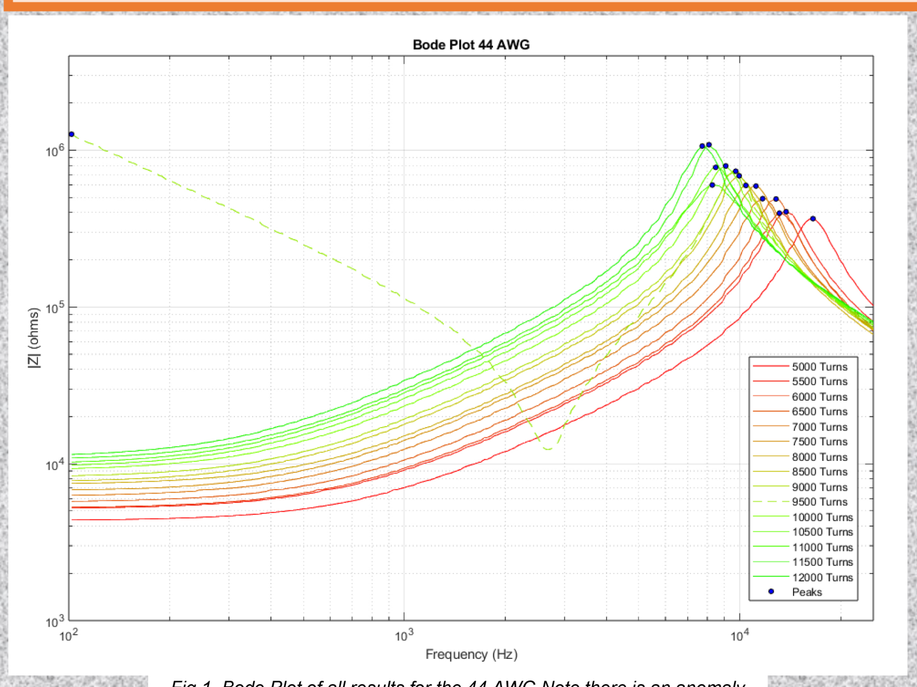

Fig 1. Bode Plot of all results for the 44 AWG Note there is an anomaly

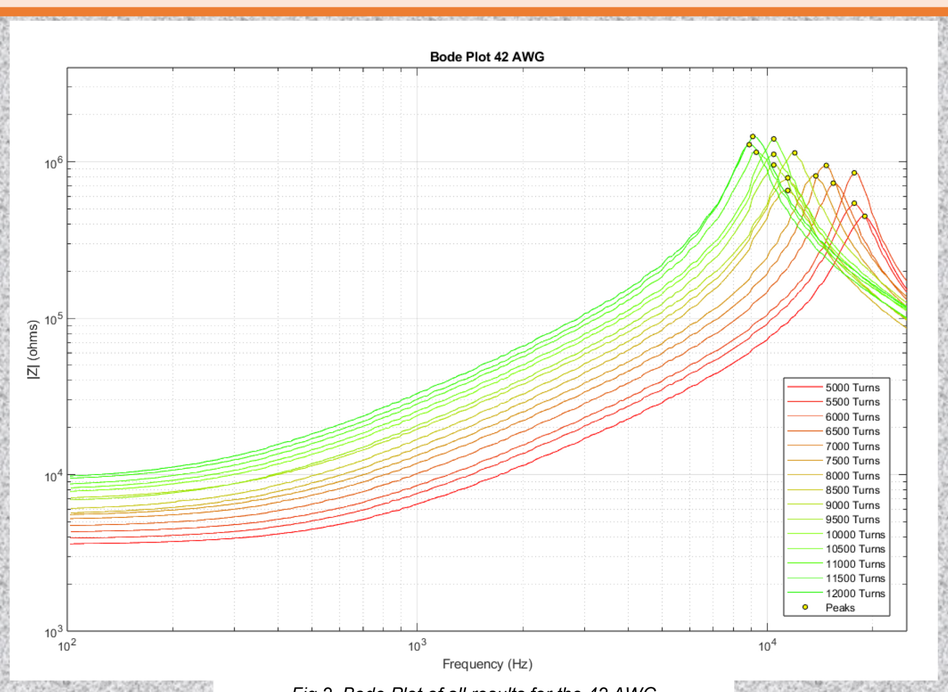

Fig 2. Bode Plot of all results for the 42 AWG

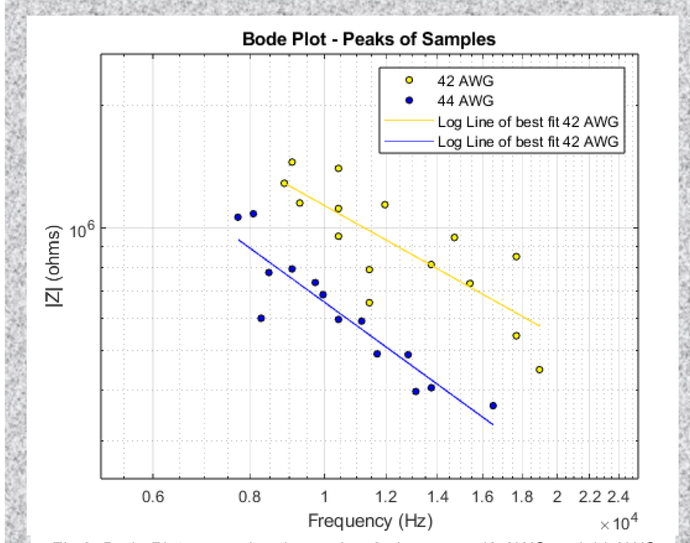

Fig 3. Bode Plot comparing the peaks of wire gauge 42 AWG and 44 AWG

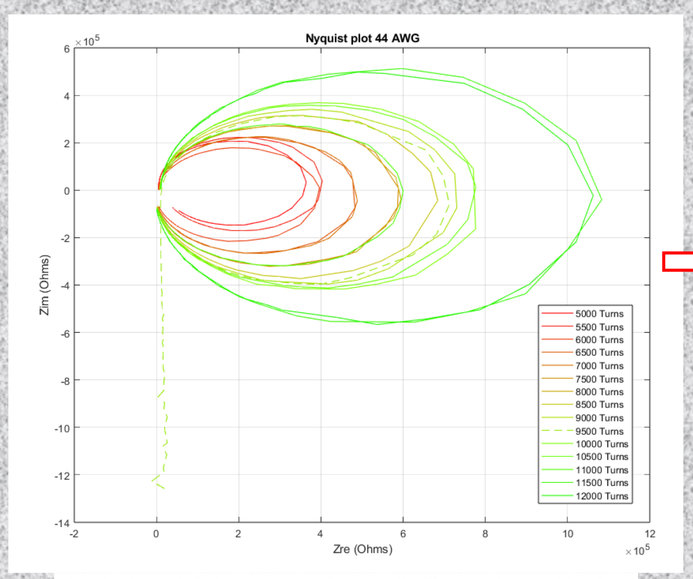

Fig 4. Nyquist Plot of all results from 44 AWG, Used for identification and to validate a system stabilisation.

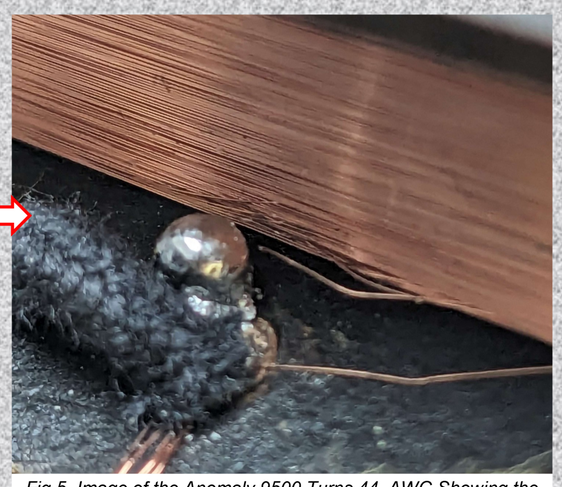

Fig 5. Image of the Anomaly 9500 Turns 44 AWG Showing the cause of the unstable results is a break in the cable.

Discussion

- The two bode plots of the 44 AWG and 42 AWG cable pickups show a **clear relationship and the quantity of turns in the pickups,** by increasing the quantity of turns (increasing the inductance) the peak is shifted to lower frequencies and the peak is gradually increased. Confirming existing equations and relationships [2] Through precise tailoring coils can be manufactured to have specific frequency responses.
- Comparing the two wire gauges directly show the gauge has an effect, being an increased wire gauge (increasing resistance) the peaks are lower for the same quantity of turns and have shifted to lower frequencies, seen in figure 3. **The Lines of best fit can be misleading as the scale is logarithmic. The relationship is exponential**
- For the anomaly of 9500 Turns 44 AWG. Using a Nyquist plot, a straight line instead of only a complete circle shows there is an addition of a capacitance within the circuit [1]; This creates a low pass filter thereby increasing the bass tones. Using visual inspection it is clear it is due to a broken coil cable. Either attributable to poor handling or manufacture error. **This shows how faults can have a dramatic effect on performance.**

Future work

As this is an on going project in collaboration with another university there are still more analyses to be derived and more conditions under which the pickups will be tested underneath. Additional research would be:

- Investigating output variations with an amplifier load connected and with varying amplifier settings.
- Varying the manufacturing wire winding pitch on the pickups
- Varying the magnetic core of the pickups
- Additional analysis in comparison to model simulations of ideal components

References and Acknowledgements

[1] Jonscher, A K. (1983) Dielectric relaxation in solids. London: Chelsea Dielectrics Press Limited (70)

[2] Zollner, M, Zwicker, T.(2019) Factoring in the Q. GITEC. Available from: https://www.gitec-forum-eng.de/wp-content/uploads/2022/01/Z52E_Q-Factor-TMWTMW.pdf [accessed 20 June 2023]

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