Reduction of RFI for the Mobile User

By M5BTB

Based on 'Radio Interference from Car Ignition Systems' M.Phil. thesis (1977)

- Sponsored by Ford Motor Company

How the Vehicle can Interfere with the Mobile User

- Conduction of interference
- Radiation of interference
- The only real way to limit RFI is at source
- Trying to reduce the interference effect in the vicinity of the equipment is too late

CISPR/D - EMC Regulations Specify Maximum Interference Levels

- CISPR - Standardization of limits and methods of measurement for control of radio frequency disturbances (including interference to on-board radio reception arising from devices within the product itself) from:
- - Self propelled equipment powered by internal combustion engines, electrical motors or a combination thereof including but not limited to Road Vehicles and boats (under 15 m in length)
- - All equipment/machines equipped with an internal combustion engine.

Quasi-Peak Measurement

- Ignition interference levels are measured using a CISPR radio receiver with a quasi-peak detector
- The detector circuit has charge and discharge detector time constants that help pick out the severity of impulse interference – as you would get from a spark

Bad RFI Suppression may Affect :

- Amateur radio equipment
- In-car video/audio equipment
- Engine Management Unit
- Other road users with susceptible equipment

Methods to reduce Vehicle RFI (1)

- Tyre earthing
- Audio clipping
- Alternator filtering
- Internal combustion engine RFI suppression (distributor/spark plug)

Methods to reduce Vehicle RFI (2)

- Antenna position
- RF live bonnet earthing
- Power supply filtering and earthing
- Effect RFI reduction by using low susceptibility equipment
- Control of rust (earthing) in the antenna vicinity

Tyre Earthing Methods

- Tyres running over white road lines change the local vehicle RF earthing which can lead to change in background noise affecting squelch effectiveness.
- Tyre rubber conductivity
- Conductive tyre paint

Audio Clipping Circuitry

- When RFI breakthrough occurs, there may be a receiver facility to automatically ‘clip’ breakthrough using sample and hold circuitry – though this can create its own audio distortion.

Alternator Filtering

- No sparking expected in alternators, but induction distortion can lead to some frequency interference effects.
- This distortion can be reduced by use of an alternator filter.

Rust

- Significant work has been done to reduce the ‘non-linear diode effect’ on co-located military receiver antenna systems using a range of frequencies causing frequency spreading.
- Radio amateurs normally transmit on one frequency, so ‘spreading’ should not be a problem
- Any vehicle, new or old, can generate RFI.

Antenna Position

- Antenna position to be well away from engine compartment
- Car bonnet hinge earthing may not be adequate, and the structure could become an intermediate antenna (re-radiating engine compartment interference to mobile antenna)

Ignition System Sources of Radio Interference

- This is the main source of interference that the radio amateur may have problems with.

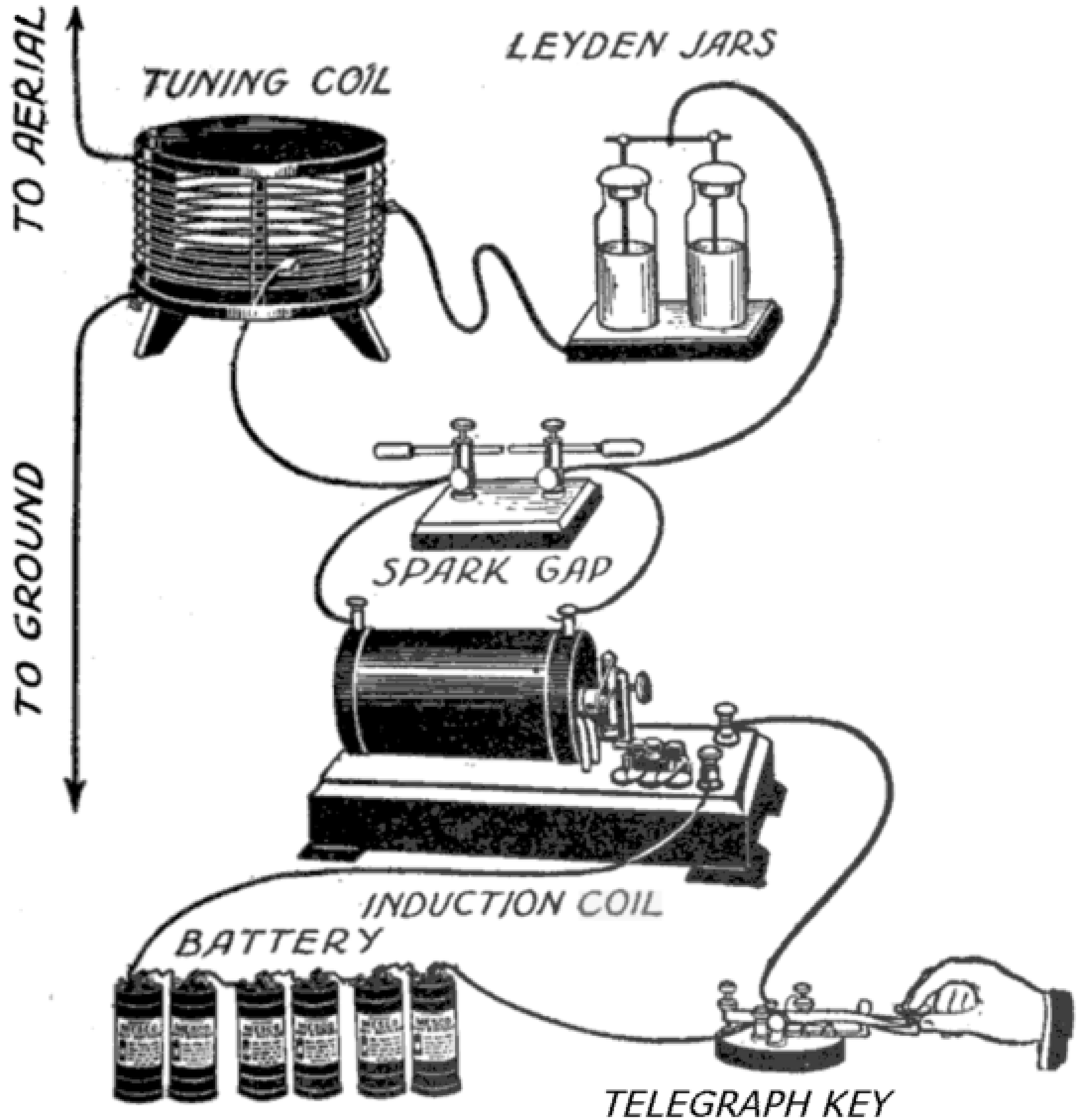
Ignition System Sources of Radio Interference

- Spark Plug – high capacitance spark discharge
- Distributor – low capacitance spark discharge
- HT Lead – resonant antenna cable with primary discharge sources at either end

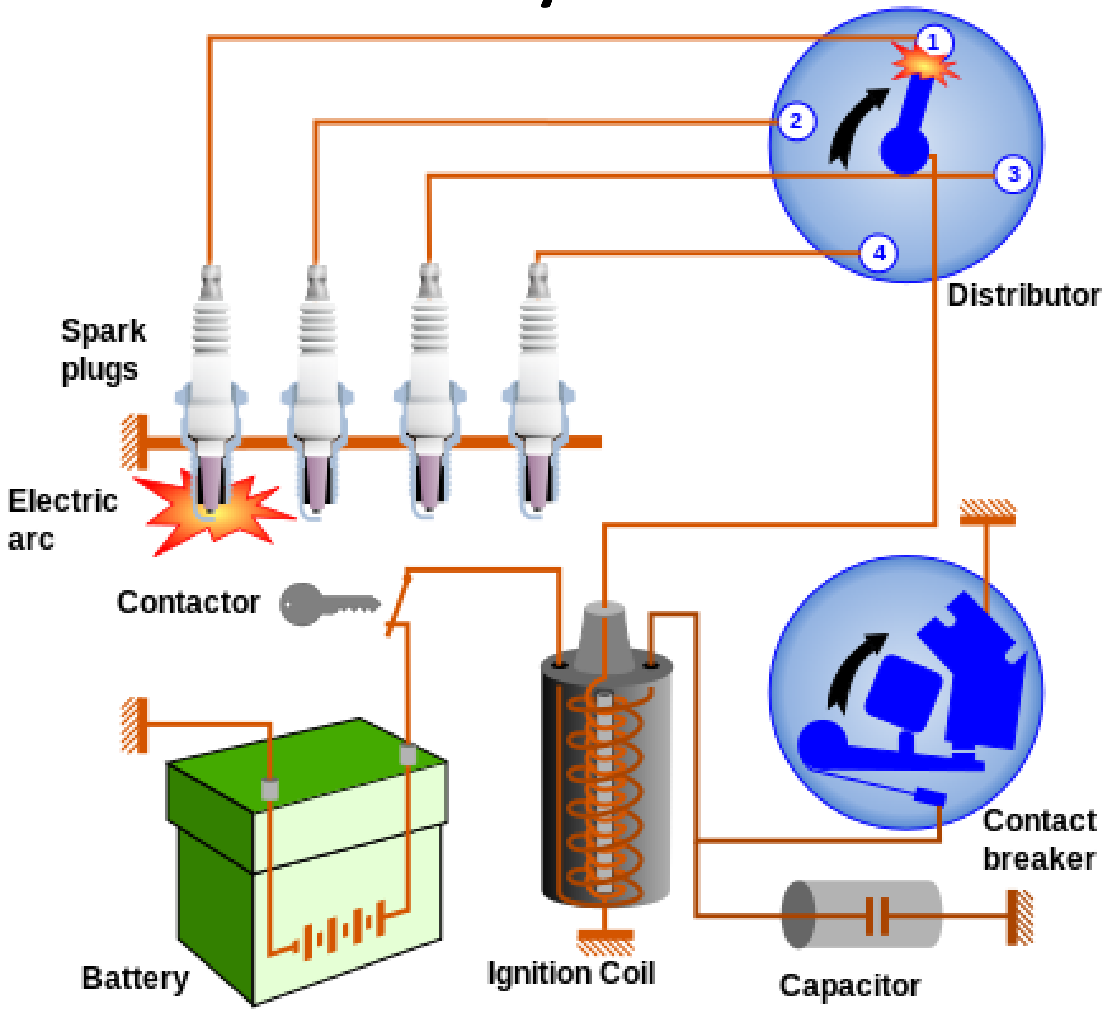
Diagram of Internal Combustion Engine (ICE) Ignition System

- The ICE ignition system is similar to the original RF transmission equipment (spark gap generator)
- RF transmissions were so broadband and uncontrolled that they were withdrawn on the 1930’s

Spark Gap Generator



Internal Combustion Engine Ignition System



Resonance Problem in Ignition System

- There are two interference generating spark sources – spark plug and distributor
- The ignition leads (Low Tension + High Tension) act like transmitting resonant antennas
- Point source radio interference is due to the erratic nature of the spark. This may be reduced by minimising spark current by resistors near sparks
- HT lead resonance is reduced by continuously resistive leads
- Screening of HT cables may lead to insulation breakdown

Typical Spark Plug Operation

- Plug strikes at ~7kV
- Discharge of spark plug capacitance by RFI generating spark
- Most plug gap energy is from capacitance discharge
- Capacitance discharge is maintained at a plug gap voltage of 500V – 1kV
- Capacitance discharge is erratic, generating RF energy

Ignition System Sparks (1)

Earth Cone

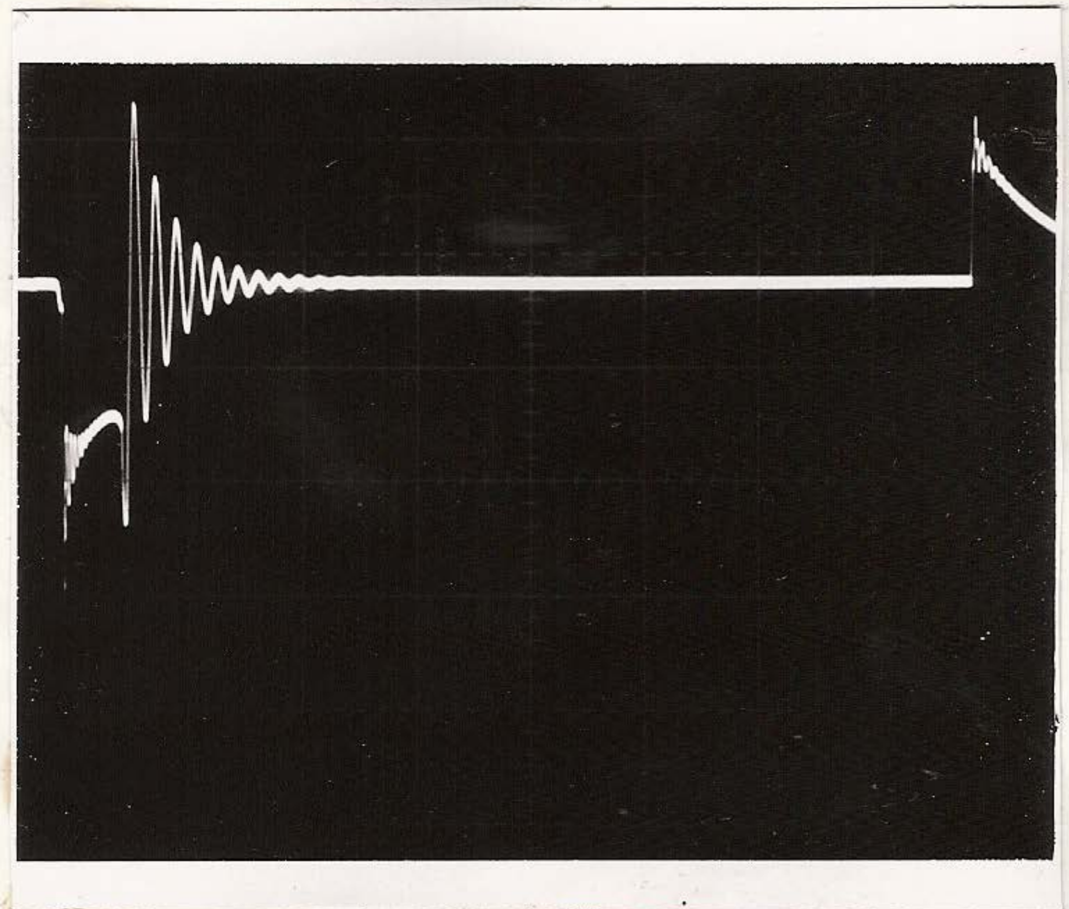


Fig. 7.1

Coil waveform

2ms/div.

1kv/div.

Ignition System Sparks (2)

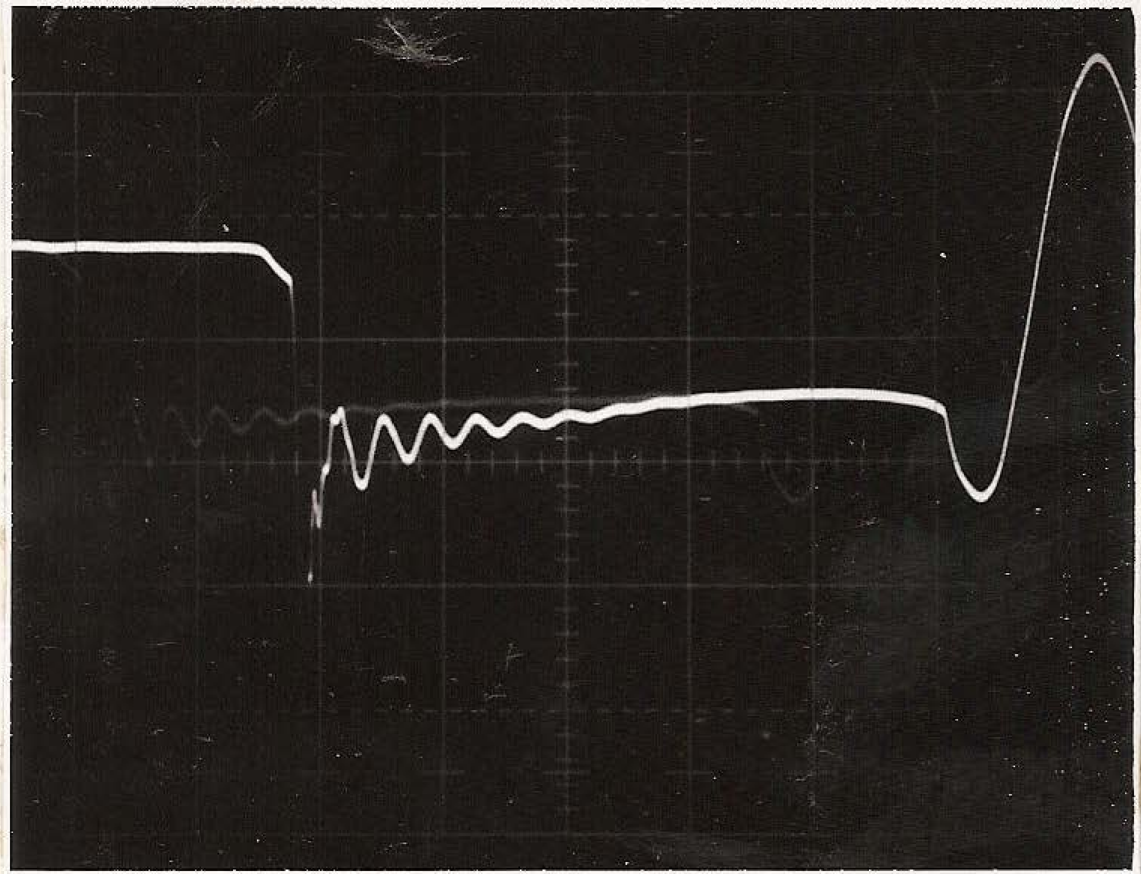


Fig. 7.2

Coil waveform

0.2ms/div.

1kv/div.

Ignition System Sparks (3)

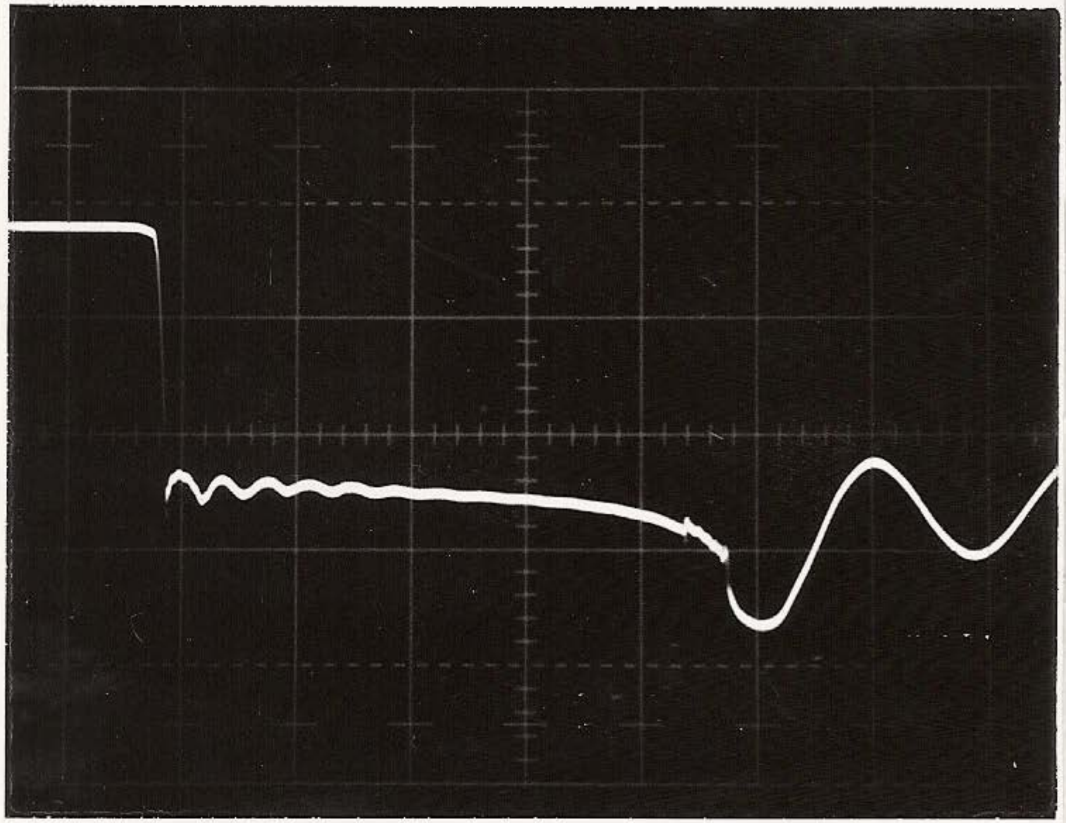


Fig. 7.3

Spark Plug waveform

0.2ms/div.

200v/div.

Radiated Interference (1)

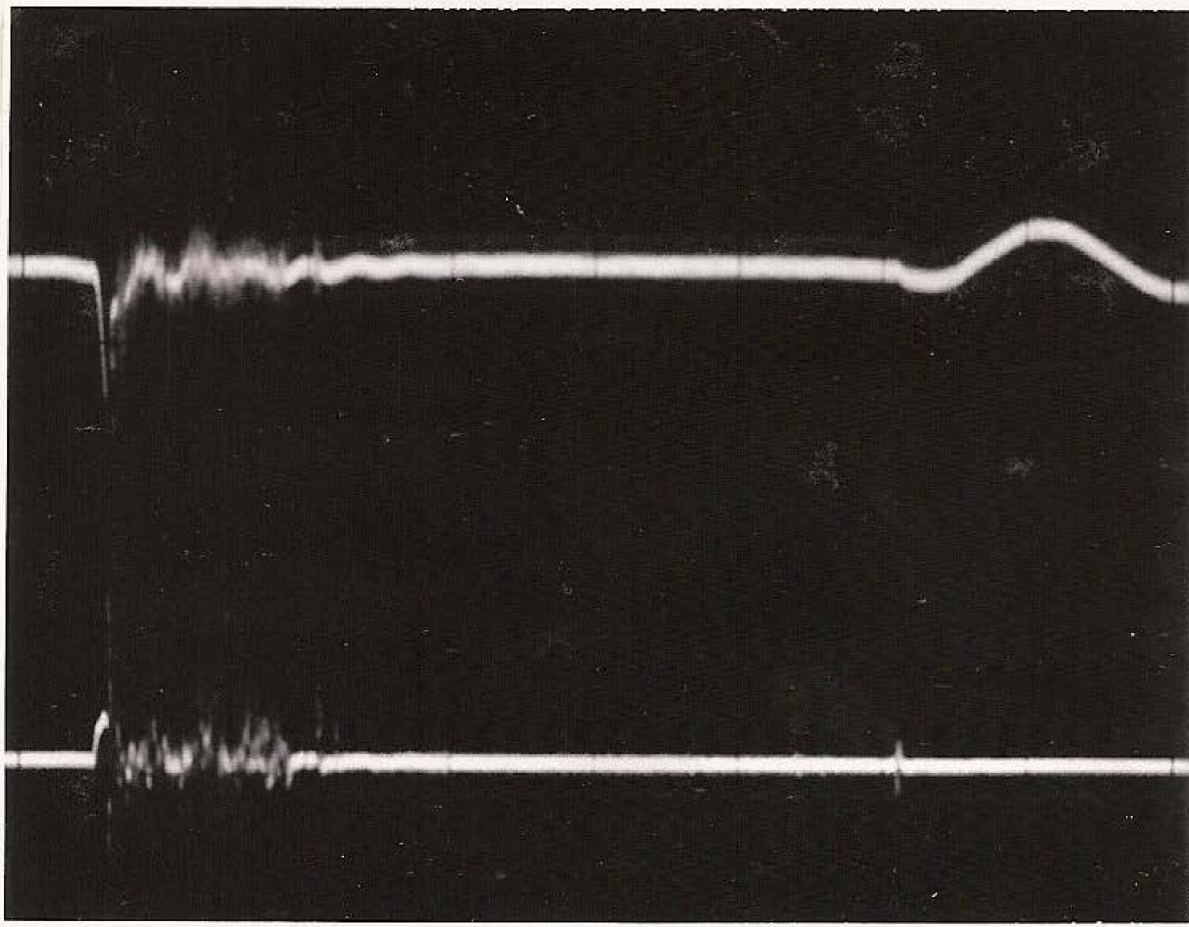


Fig. 7.4

Dipole and interference waveforms

0.2ms/div.

Radiated Interference (2)

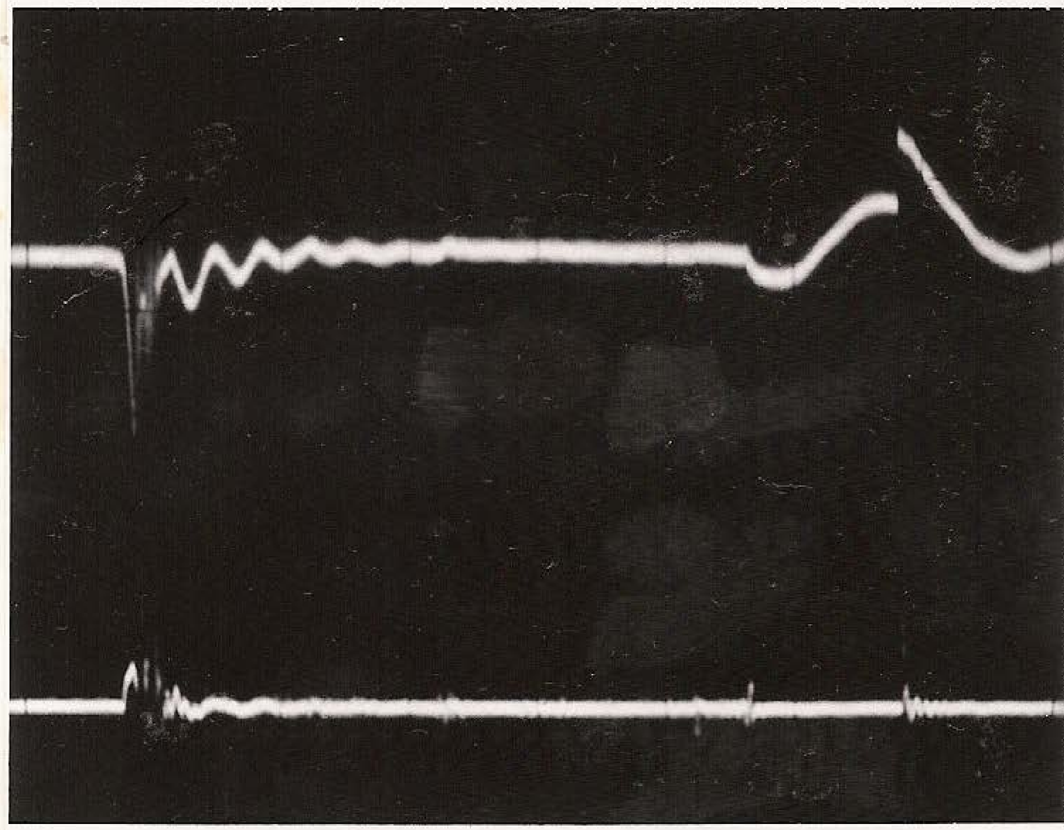


Fig. 7.5

As above

(re-strike after

extinction)

Radiated Interference (3)

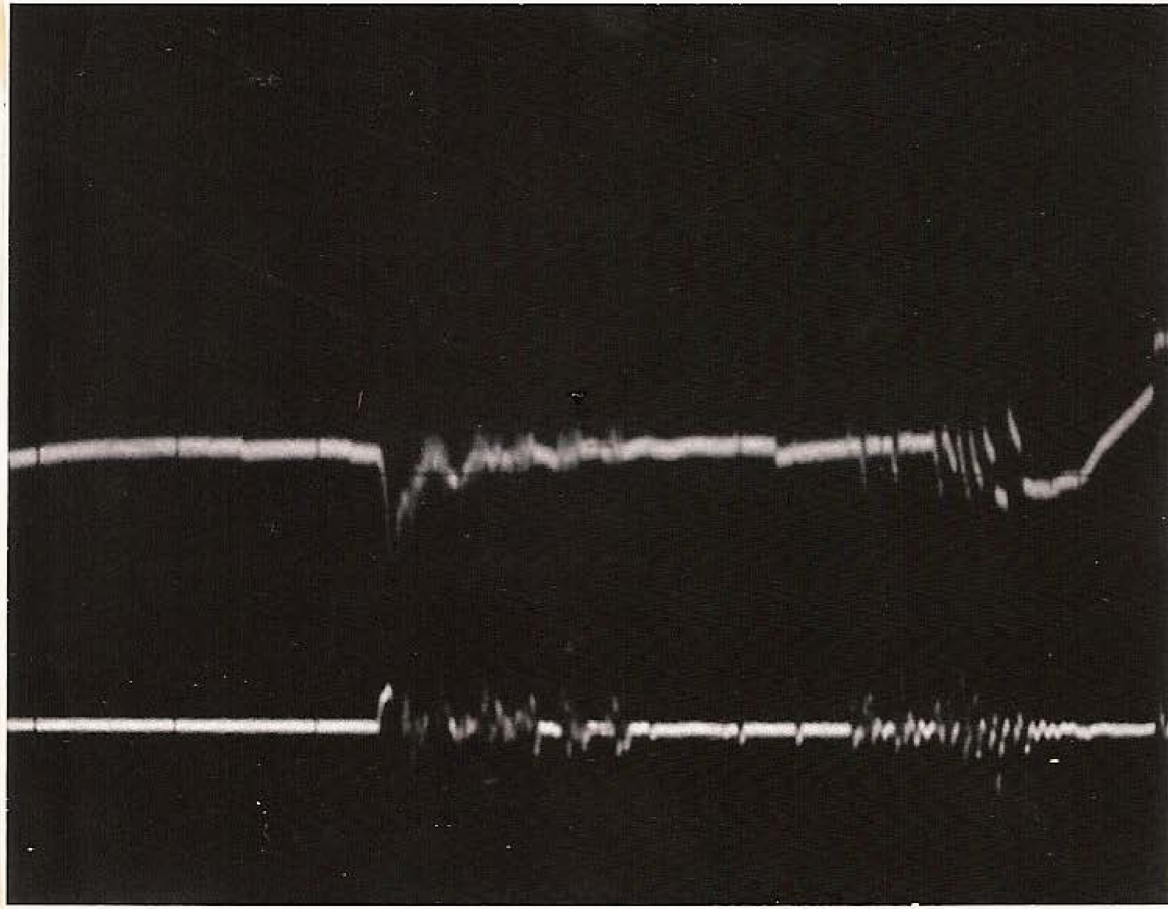


Fig. 7.6

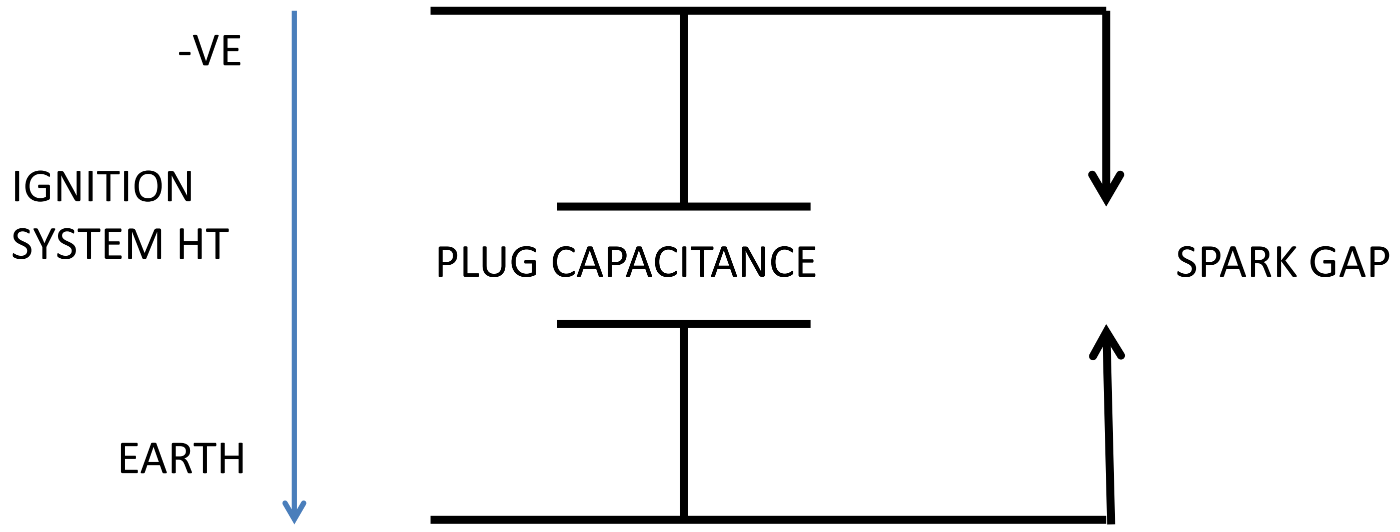
As above

(Erratic arc)

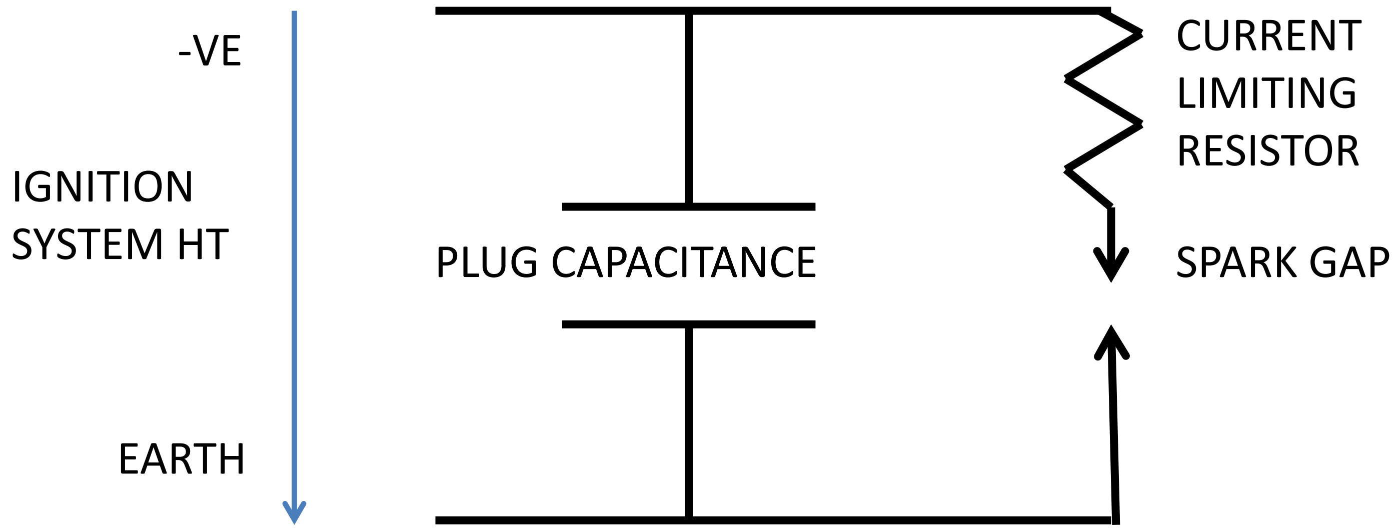
Typical Spark Plug

Detail of Spark Plug – central and lateral electrodes

Spark Plug Circuitry



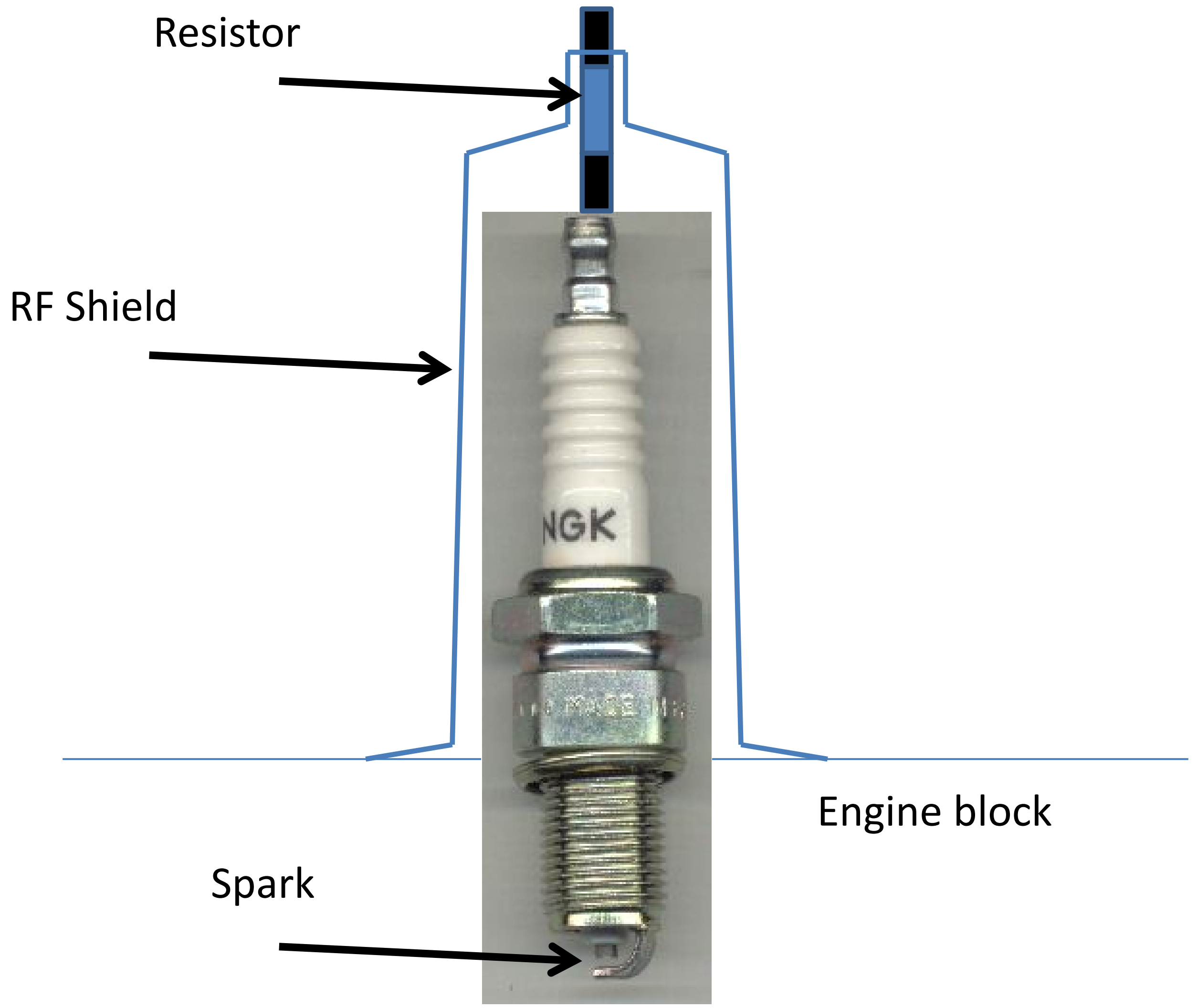
Resistive Spark Plug – RF energy can be dissipated with the use of well placed resistance



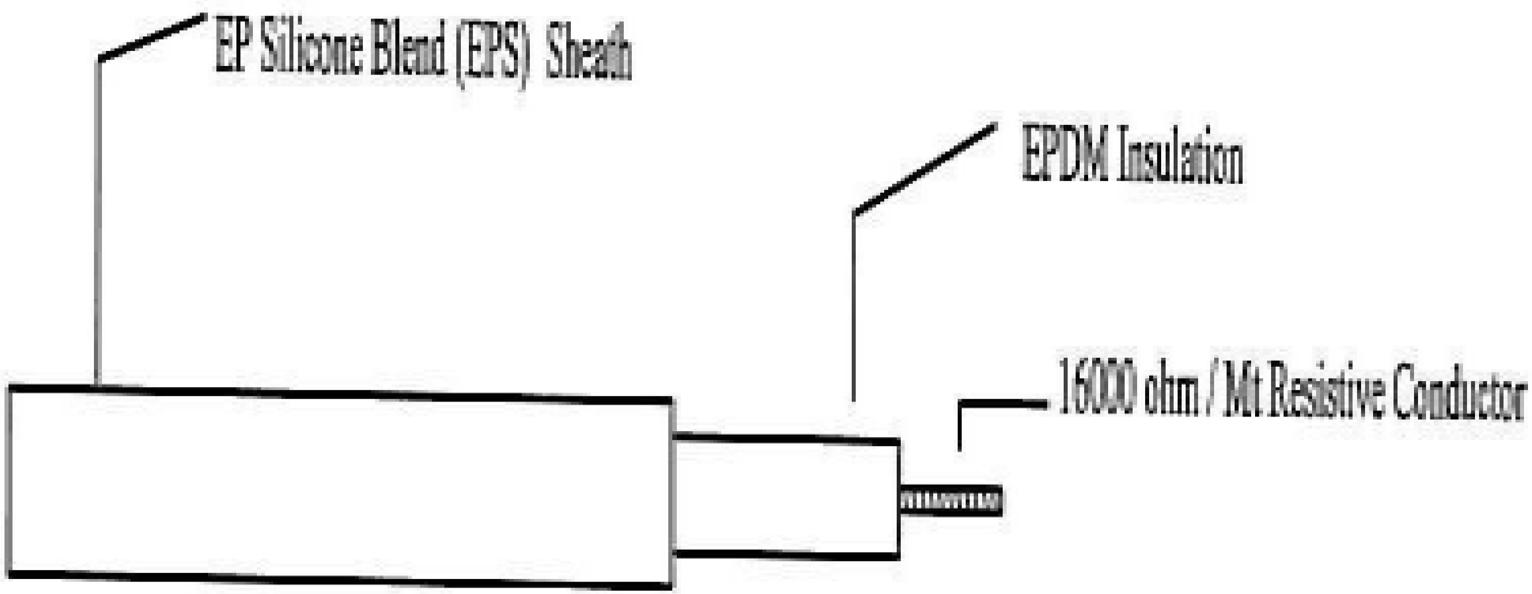
Spark Plug Discharge Energy

- With the assumed spark plug capacitance of 10pF and discharge voltage of 7kv, the spark energy discharged would be in the region of 250 microwatts
- This is equivalent to about -6dBm, ie. a quarter of a milliwatt
- This discharge energy is repeated for each spark
- A fair proportion of this discharge energy is emitted as electromagnetic energy (e.g. RF + light) as well as heat

Spark Plug Resistive Shield



Resistive HT Cabling e.g. SIPCON (Spiral/Resistive Conductors may also be used)



What Next ?

- Comparative measurements need to be made to ascertain relevant effectiveness of each suppression component to the car ignition system
- This can be done under laboratory conditions
- The laboratory results can be compared with actual vehicle antenna measurements
- Near and far field interference must be measured.

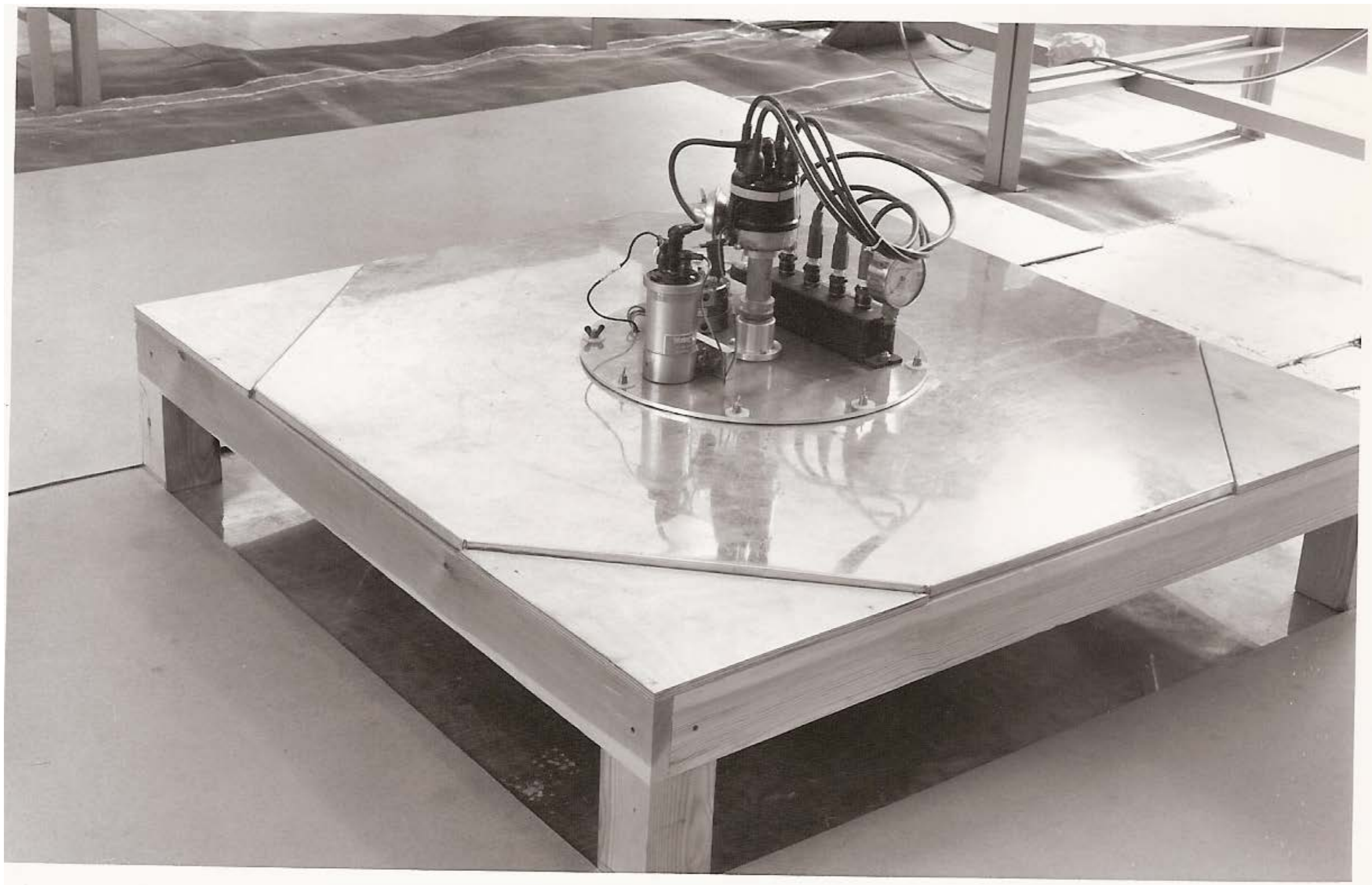
Laboratory Equipment

- As described in Professor E Fromy in his paper ‘Earth Current Method for Laboratory Measurement of Power Radiated in the Range 30 – 1000MHz’ (1961)

Equipment :

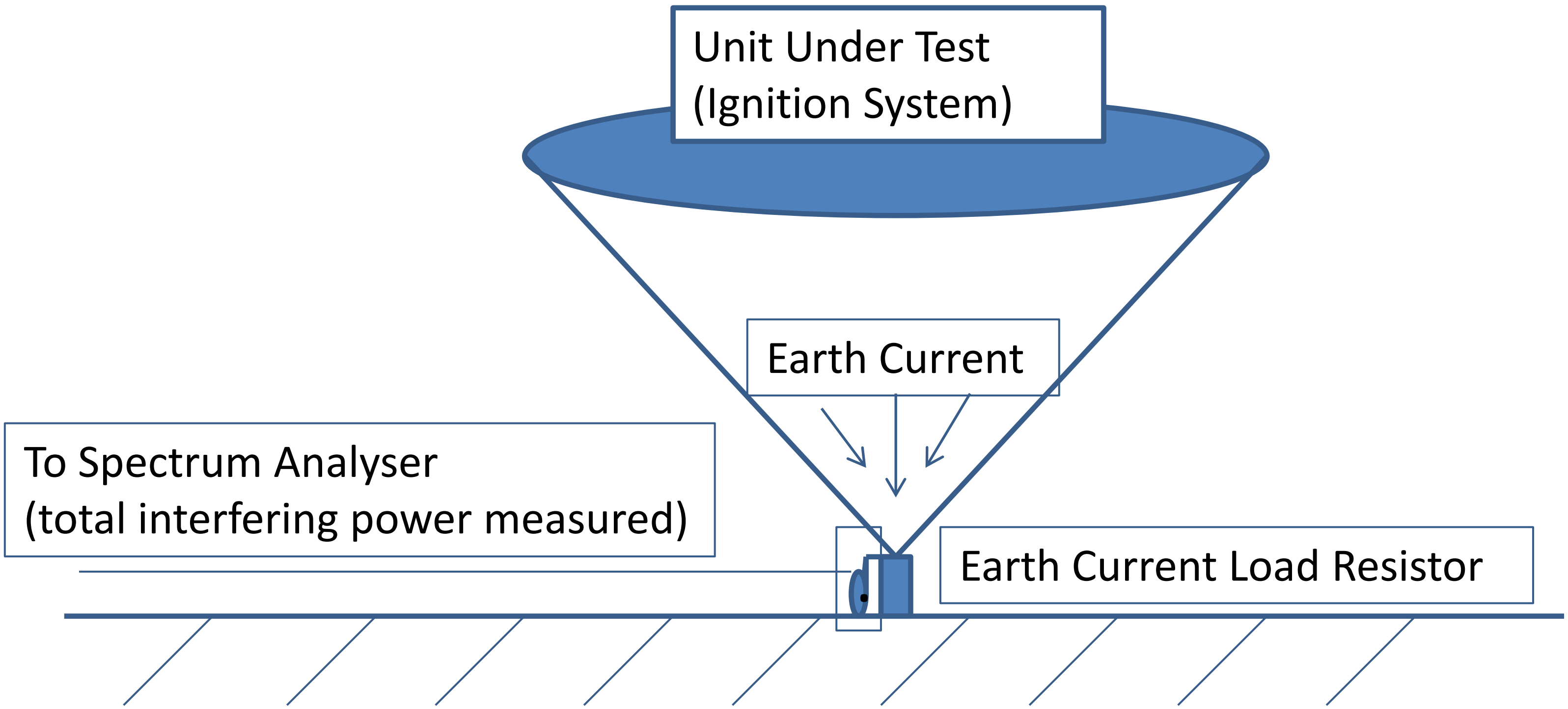
- Laboratory Marconi spectrum analyser TF2370
- Laboratory installed car ignition system on discone antenna surface, mounted on earth plane (correlated to actual car measurements – Ford Capri in local car park)

Realisation of Laboratory Car Ignition System



EARTH CONE AND IGNITION SYSTEM (Earth plane in background)

Physical Representation of Discone Test equipment



Test Variables

- Wire/resistive HT leads
- Standard/resistive rotor (distributor)
- Standard /resistive spark plugs
- Standard/spark resistive plug shields

Results taken for Long Wave, Medium Wave and VHF (Band II), for both the discone equipment and a loaned Ford Capri in the departmental car park

Interference Spectrum measured by Marconi TF2370 Spectrum Analyser

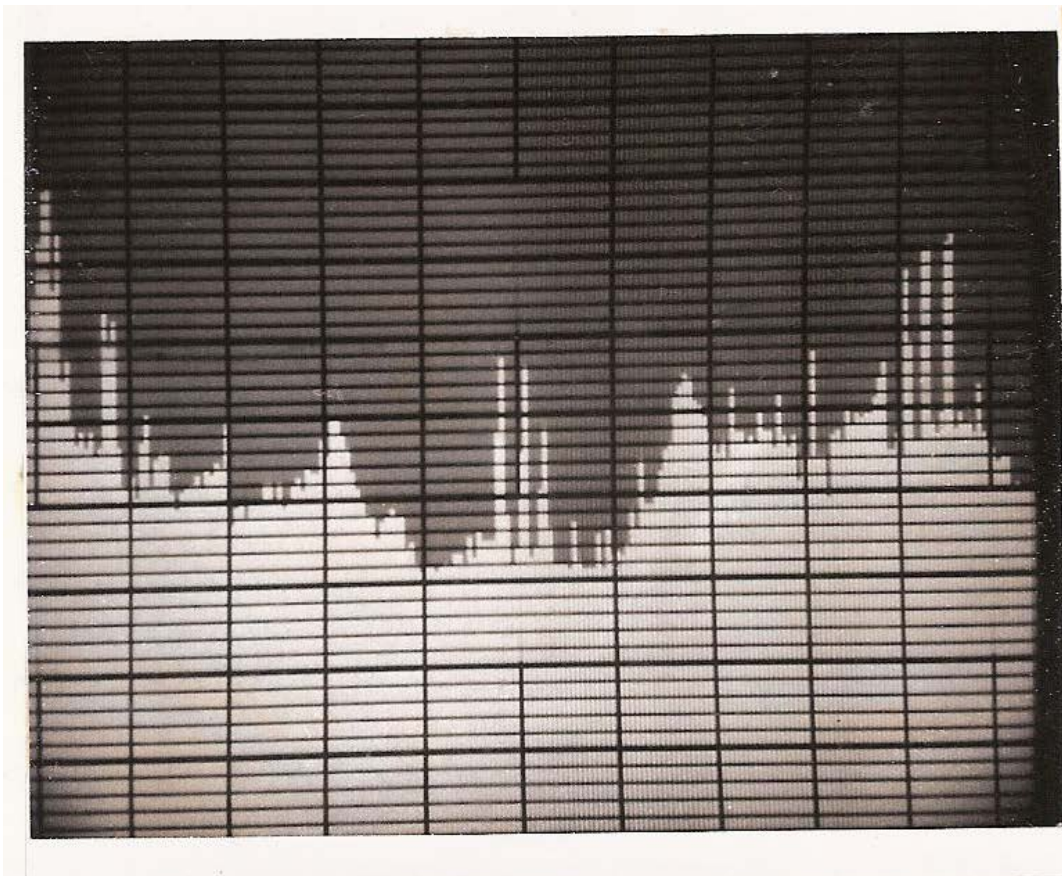


Fig. 4.1

Ford Capri

SIPCON reference

0dBm datum

50kHz B.W.

10MHz/div.

10dB/div.

(50MHz centre)

Interference Spectrum

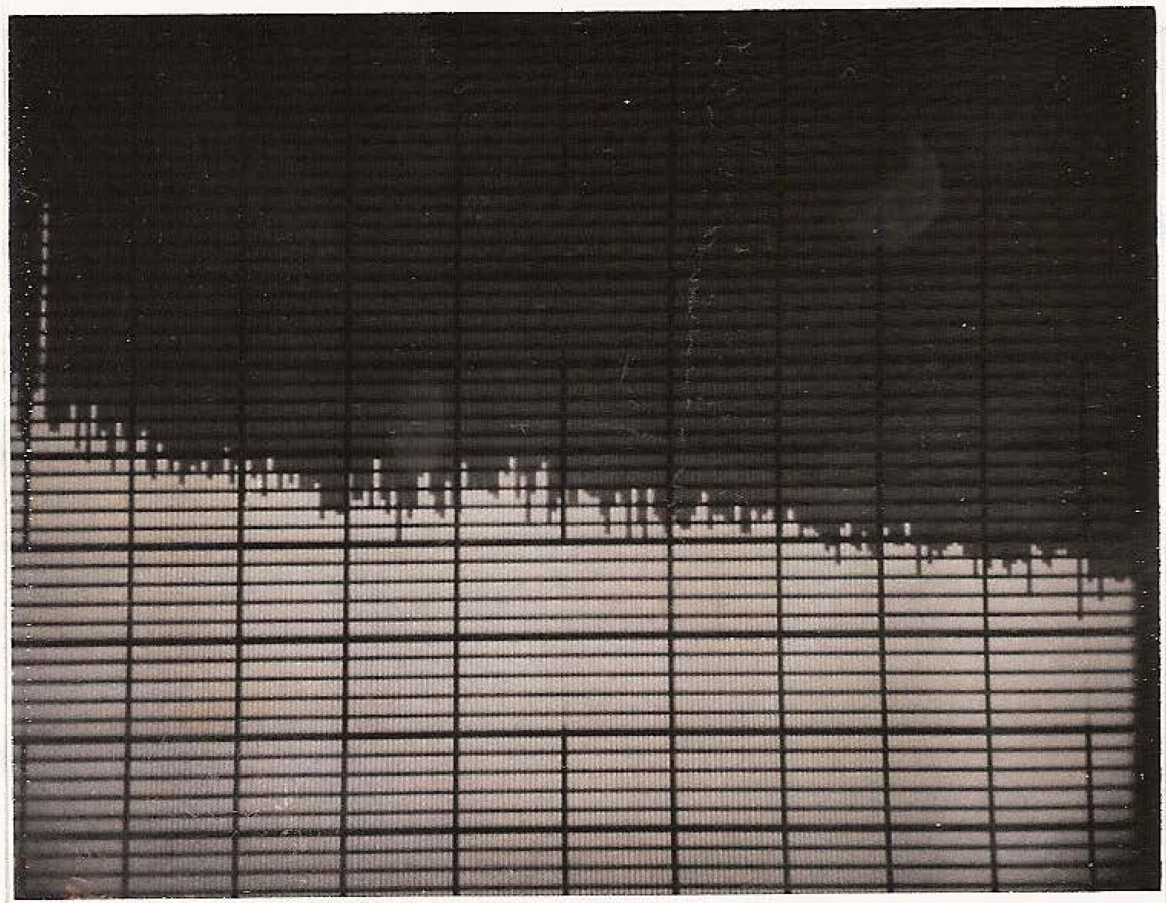


Fig. 4.2

Earth Cone

SIPCON reference

+20dBm datum

(as above)

Interference Spectrum

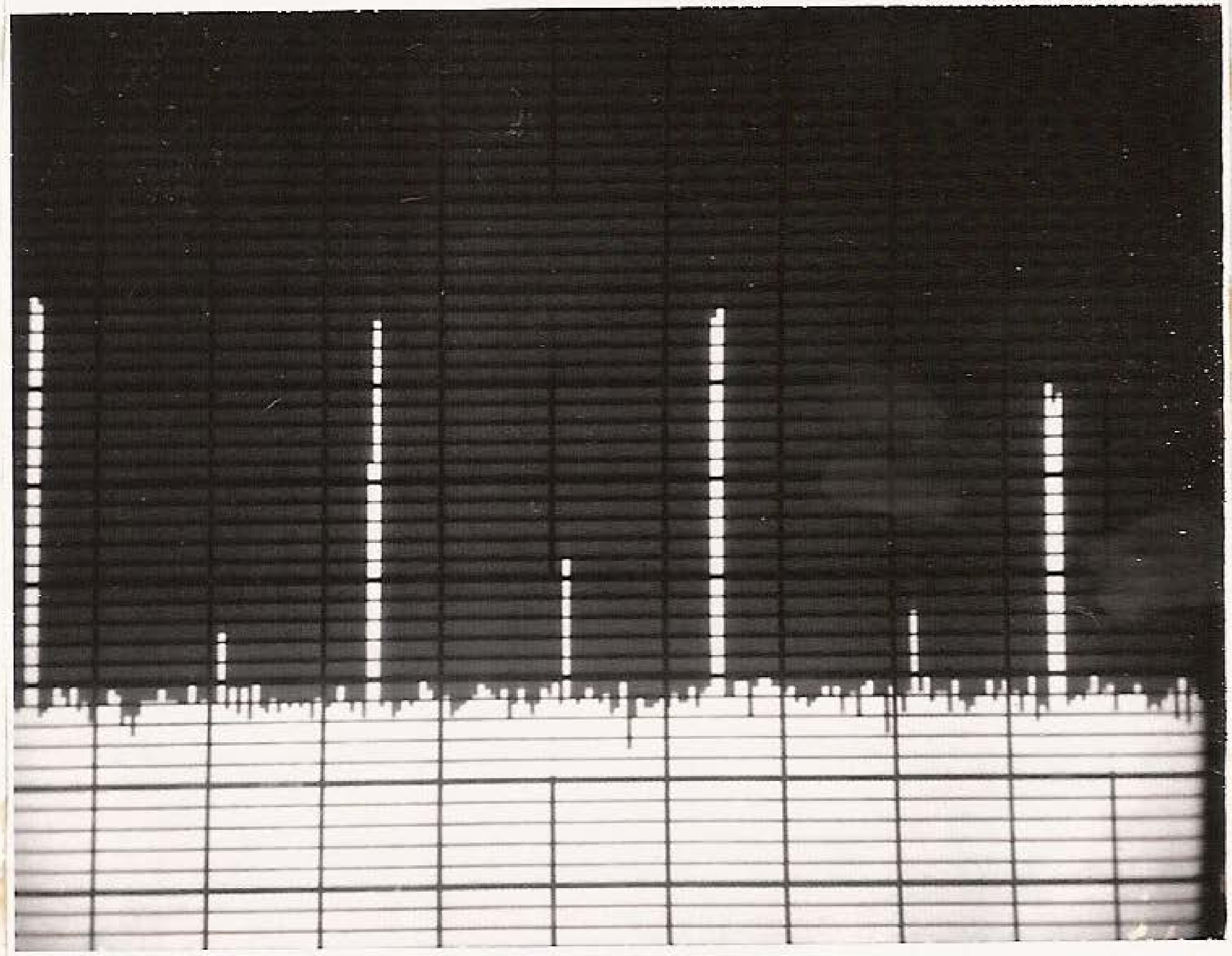


Fig. 4.3

Individual interference spectra from Earth Cone 100ms sweep time (30MHz centre)

Test Results

- There were several hundred spectrum analyser photographs taken

  General conclusions, in order of RFI suppression effectiveness for both test setup and Ford Capri, are as follows :

1. Resistive HT leads
2. Resistive spark plugs
3. Resistive distributor rotor
4. Resistive plug shields

Unintentional Problems

- There are always self inspired car mechanics who, upon trying to resolve an ignition problem, replace all RFI suppression components with standard ones.

- And they forget to replace them with the resistive equivalents when the fault has been resolved !