Radio Frequency Interference RFI

Presented by: Keith Witney VE7KW

- Radio Frequency Interference RFI
  - Standards
  - From our equipment
  - To our equipment
  - Mitigation
RFI The basics

- Every semiconductor junction is a square-law DETECTOR so reducing signal by 1/2 reduces RFI by 1/4
- Our houses are full of antennas; power lines, telephone lines, speaker cables, CAT cables, smoke detector wiring, alarm wiring
- Differential signals (antenna feedlines, CAT5) cancel because current in one conductor is cancelled by the current in the opposite conductor (for coax on the inside of the shield)
- Common mode: voltage between ends of cable different but no voltage between the conductors (for coax causes current on the outside of the shield)
- Imbalance causes a differential signal to be created from CM
RFI Standards

- Lets be realistic
  - Noise exists
    - Cosmic
    - Lightning
    - Internal to our rigs
      - Thermal
        (unless at absolute zero)
## RFI Standards

### ITU-R P.372-7 Noise

<table>
<thead>
<tr>
<th>S Units</th>
<th>dBm</th>
<th>dBuV</th>
<th>uV 50Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>S9</td>
<td>-73</td>
<td>44</td>
<td>50.2</td>
</tr>
<tr>
<td>S8</td>
<td>-79</td>
<td>28</td>
<td>251.</td>
</tr>
<tr>
<td>S7</td>
<td>-85</td>
<td>22</td>
<td>12.6</td>
</tr>
<tr>
<td>S6</td>
<td>-91</td>
<td>16</td>
<td>6.3</td>
</tr>
<tr>
<td>S5</td>
<td>-97</td>
<td>10</td>
<td>3.2</td>
</tr>
<tr>
<td>S4</td>
<td>-103</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>S3</td>
<td>-109</td>
<td>-2</td>
<td>0.8</td>
</tr>
<tr>
<td>S2</td>
<td>-115</td>
<td>-8</td>
<td>0.4</td>
</tr>
<tr>
<td>S1</td>
<td>-121</td>
<td>-14</td>
<td>0.2</td>
</tr>
</tbody>
</table>

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RFI Standards Tx

IC CPC 3-14-01

- These are the levels at which IC would regard you to be at fault
- 125dBµV/m is generated by 75W to a dipole at ~30m

<table>
<thead>
<tr>
<th>TYPE OF EQUIPMENT</th>
<th>FIELD STRENGTH CRITERION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dBµV/m</td>
</tr>
<tr>
<td>Broadcasting Receivers</td>
<td>125</td>
</tr>
<tr>
<td>Associated Equipment</td>
<td>125</td>
</tr>
<tr>
<td>Radio-Sensitive Equipment</td>
<td>130</td>
</tr>
</tbody>
</table>

- Associated Equipment
  - Audio/video recorders etc.
- Radio-Sensitive Equipment
  - “any device, machinery or equipment, other than radio apparatus, the use or functioning of which is or can be adversely affected by radio communication emissions.” baby-monitors, telephones, security systems.
RFI Standards Rx

- IC emissions standards Class B (residential)
- Information Technology Equipment
  - Conducted emissions limit
    - Powerline 0.5-5 MHz 56 dBuV Quasi-peak, 46 dBuV average
    - 5-30MHz 60 dBuV Quasi-peak, 50 dBuV average
  - Radiated
    - Powerline 1.705-108 MHz 40 dBuV/m at 3m
- These limits are all >S9! (~S4 at 300m, ~S1 at 3 km)
- There is evidence of circuit boards with provision for EMI filters but with components not installed in production (to save cost).
RFI From our equipment

TVI
- Not your plain old TVI anymore
  - Unlikely to be IF/front end overload
  - More likely to be from system interconnections
- Now mainly delivered by Cable/twisted pair
  - Both offer significant “shielding” when installed properly
  - Telus Optic does seem to be sensitive to 14 MHz
    - Coax connection only not CAT5
      - CAT5 will radiate spurs so needs Ferrite choke(s)
RFI From our equipment

Audio
- Lots of unshielded, unbalanced cable
- No equipment shields
- “Pin 1” problems
  - Input shields not connected to metallic ground shield.
RFI From our equipment

Other

- Garage door operators
  ▶ Older units only?
- Smoke alarms
  ▶ Pick up on unshielded, unbalanced wiring
- Shaw IP telephone control signals on 21 MHz!
  ▶ At least they recognise that it is their problem!
- The neighbour’s Lazy Boy!
  ▶ The plants died, the Cat is sick and the gold-fish is tarnished
RFI To our equipment

- - - - - - - - - - - - - - - - - - -

- ADSL/VDSL/XDSL
  - Aka Telus Optic, Shaw is the same with coax
  - 1 to 30 MHz
    - Trying to send 3-4 channels or 10-15 MHz of bandwidth
    - Ham band notches to -80dBm/Hz (approx S7) at 10m
  - Twisted pair offers 10-30 dB attenuation (when installed correctly)
  - Notches known “in use” frequencies
    - Amateur radio is intermittent and not channelized
  - May be dynamically allocating notches so use it or lose it as allocation is based upon BER.
Telus Optic Spectra
At distribution coax

DG8SAQ Vector Network Analyzer Software
09/28/2012 10:05:53 PM 20100829 telus optic attached to TV record 1 ch 4 live hd

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>dB</th>
</tr>
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<tbody>
<tr>
<td>1. 7.17 MHz</td>
<td>-511 dB</td>
</tr>
<tr>
<td>2. 10.09 MHz</td>
<td>-58.32 dB</td>
</tr>
<tr>
<td>3. 14.2 MHz</td>
<td>-51.47 dB</td>
</tr>
<tr>
<td>4. 18.1 MHz</td>
<td>-50.01 dB</td>
</tr>
<tr>
<td>5. 21.25 MHz</td>
<td>-52.17 dB</td>
</tr>
<tr>
<td>6. 24.33 MHz</td>
<td>-54.94 dB</td>
</tr>
<tr>
<td>7. 28.08 MHz</td>
<td>-54.23 dB</td>
</tr>
<tr>
<td>8. 51.75 MHz</td>
<td>-63.22 dB</td>
</tr>
<tr>
<td>9. 3.74 MHz</td>
<td>-49.85 dB</td>
</tr>
</tbody>
</table>

TX Att. = 32.6 dB

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Before/After Telus Optic
17m dipole

S4~ -106 dB
No significant difference

D68SAQ Vector Network Analyzer Software
6/11/2012 5:55:45 PM 20120611 optic mem3 before and after

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>S21 dB</th>
<th>S11 Smith</th>
<th>Mem2 VSWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 7.11</td>
<td>-95.93dB</td>
<td>-97.81dB</td>
<td></td>
</tr>
<tr>
<td>2 10.13</td>
<td>-102.55dB</td>
<td>-92.85dB</td>
<td></td>
</tr>
<tr>
<td>3 14.13</td>
<td>-94.66dB</td>
<td>-101.79dB</td>
<td></td>
</tr>
<tr>
<td>4 18.13</td>
<td>-93.58dB</td>
<td>-101.25dB</td>
<td></td>
</tr>
<tr>
<td>5 21.11</td>
<td>-102.84dB</td>
<td>-101.15dB</td>
<td></td>
</tr>
<tr>
<td>6 24.89</td>
<td>-99.69dB</td>
<td>-97.98dB</td>
<td></td>
</tr>
<tr>
<td>7 28.09</td>
<td>-98.04dB</td>
<td>-104.14dB</td>
<td></td>
</tr>
</tbody>
</table>

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Comparison of ITU and Measurements (~2.3kHz BW)

Noise test comparisons

- R8 R0 VNWA
- R8 VNWA
- K3
- Dip Nov12
- dip Mar13
- ITU Sub
- VA7OJ
- VE7KW
VA7OJ (Perseus R8)
VE7KW (Perseus R8)
RFI To our equipment

- Digital Controllers
  - Air conditioners
    - Variable speed motor controllers
  - Solar power converters
    - Apparently these are becoming a real problem as are basically high power switch mode power supplies mounted nice and high
  - Washing machines
    - Variable speed drive controllers
      - Should be conforming to standards
RFI To our equipment

- - - - - - - - - - -

- Solar Power converter (RadCom Feb 2013)

FIGURE 1: Solar PV system VHF radiated emission and ambient signals.

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RFI To our equipment

- - - - - - - - - - - - - - - - - - -

- Computers
  - Don’t trust the power supply
    - Line Filter components fail without affecting the power supply output
  - Learn to hate the “wall wart”
    - Some are OK (look for recent certifications)
    - Assume are bad unless proven otherwise
  - How much RFI is your router spitting out?
    - Cause is poor driver design with no filtering
    - Spurs
    - Can be knocked down from S9 to S2 with ferrites
    - Consider using wireless
Router Noise before Ferrites 17m Dipole

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RFI To our equipment

Power Lines
- Seems to not be a big problem locally
- New installation in my area follows NPS-EC-07-002 recommendations
  ♦ Localize problems with portable receiver and ask for repair
- Street lights?
RFI To our equipment

- Motors/Welders
  - Electric motors
  - Furnaces
  - Filters should work

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RFI To our equipment

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

- Lights
  - CFD
    - Not in my experience
  - Halogen
    - Seems to be on a case by case basis
  - Dimmers
    - Not in my experience
  - LED
    - Christmas tree strings? Mine are OK.
RFI Mitigation

Clean your own house first

- Blackout house
  - Isolate and fix noise sources
  - Add ferrites/filters where appropriate
  - Attenuate the receiver and see if noise decreases more than attenuation (IMD)

- Now blame the neighbours Plasma TV
  - It will always be your problem
  - Isolate and fix a/p your house (but with minimal disruption)
    - Probably cheaper than moving
Powered house to Blackout house R8

DG8SAQ Vector Network Analyzer Software
3/10/2013 6:04:00 PM 20130310 R8 noise red house powered down mem1 blk house powered

Cursor Trace2: 1.70MHz -33.37dB

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>dB</th>
<th>1.70MHz</th>
<th>dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.715</td>
<td>-73.44dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.735</td>
<td>-73.37dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.755</td>
<td>-73.34dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.775</td>
<td>-73.31dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.795</td>
<td>-73.28dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.815</td>
<td>-73.25dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.835</td>
<td>-73.22dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.855</td>
<td>-73.19dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.875</td>
<td>-73.16dB</td>
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<td>-73.28dB</td>
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<tr>
<td>1.895</td>
<td>-73.13dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.915</td>
<td>-73.10dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.935</td>
<td>-73.07dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.955</td>
<td>-73.04dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.975</td>
<td>-73.01dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
<tr>
<td>1.995</td>
<td>-73.00dB</td>
<td></td>
<td>-73.28dB</td>
</tr>
</tbody>
</table>

TX Att. = 0 dB

S11 = Real Z

S11 dB

S11 Smith

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RFI Mitigation

Grounds

- **Good house keeping**
  - RF bond shack/house/utility grounds
  - If you have RF in the shack, fix it. It won’t be helping with RFI
    - Common mode chokes
    - Low impedance station ground
      - 1 V Common mode = 0.15V (S9+10) at Rx antenna (6ft gnd rod). Improve GND 10x or add 10x common mode imp and get 30+dB reduction (<S5)
  - Try grounding the feed line near the antenna
  - Never connect the coax shield to an antenna ground
RFI Mitigation

- Unfortunately lots of equipment will not have solid chassis grounds
  - “Pin 1” problem see W9YC (next slide)
- Clean up cables
  - Shielded is not always best. BALANCED twisted pair can be better especially with an over shield.
  - Reduce/change lengths
  - Good quality connectors/coax (Includes TV/CAT)
Radio Frequency Interference RFI

- Cable shields should be connected to the shielding enclosure not the circuit board.
- If no enclosure to “green wire” or PS gnd
- Almost all equipment incorrect.
RFI Mitigation

- Ferrites reduce Common Mode currents
  - Type 31, 43 for HF
  - Type 73 for VHF
  - Typical ??? snap-on type 73 so in-effective at HF
  - Impedance adds with more series ferrites
  - Run as many turns through as possible
    - Impedance is square of number of turns
    - If DC on the line make sure both + and – run in parallel through the ferrite to avoid saturation
    - Large “doughnut” cores best
      - Multiple turns
RFI Mitigation

Hi/Lo pass filters

- Were the “go to solution” when RFI was TV overload
- Good to have available
- Add shielding and bond all cable shields to the equipment shield
- Use twisted pair cables
  - EG cat 5 for CAT serial interfaces
RFI Mitigation

- Antenna location
  - Can reduce field strength/coupling
  - Going higher might help you as well as reduce RFI
  - Change from V to H, H to V
    - Most house wiring H
  - Go stealth to save the plants, cat and gold-fish
  - Small loop receive antennas can null noise sources
    - LZ1AQ’s measurements indicate that small magnetic loops offer no improved noise immunity over full size antennas

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RFI Mitigation

Null steering

- Works but
  - Sense antenna can be non-trivial
  - Very frequency sensitive
  - Works only for localised, stable noise sources
  - Not easy to use

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RFI Mitigation

Receiver performance, noise blankers, noise reduction

- Receive performance >> requirements
  - Watch for IMD products from strong out of band signals
  - Should not need pre-amplifier to 30 MHz
  - Use attenuation <14 MHz
  - Filtering reduces noise. Use as much as you can; 2 S unit improvement 2100 to 500 Hz.

- Modern noise blankers (impulse noise) are very effective. IF and Audio

- Modern noise reduction can also be very effective but must be tailored to the mode/noise IF and Audio
  - Audio signal processors can be easily added for NB/NR
    - After as much RF attenuation as possible
RFI Mitigation

- Power line filters
  - Common and differential mode
  - Apply at source of noise
  - Note capacitors must be X or Y rated.
RFI Mitigation
RFI References

References

- A Ham’s guide to RFI, Ferrites, Baluns and Audio Interfacing; Jim Brown K9YC
- CPC-3-14-01 - Determinations of Harmful Interference with Respect to Radio-Sensitive Equipment
- The Mitigation of Radio Noise from External Sources at receiving sites; Vincent, Munsch, Adler, Parker; Naval Post Graduate school NPS-EC-07-002
- VDSL Technology Issues - an overview; Friedman, Analogue Design 34-5 2000
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- The null steerer revisited; QST July 1994
RFI References

- www.w8ji.com/comm-mode_noise.htm
- http://www.lz1aq.signacor.com/docs/fa-eng/Weak_signals-mag_loop_engl.htm