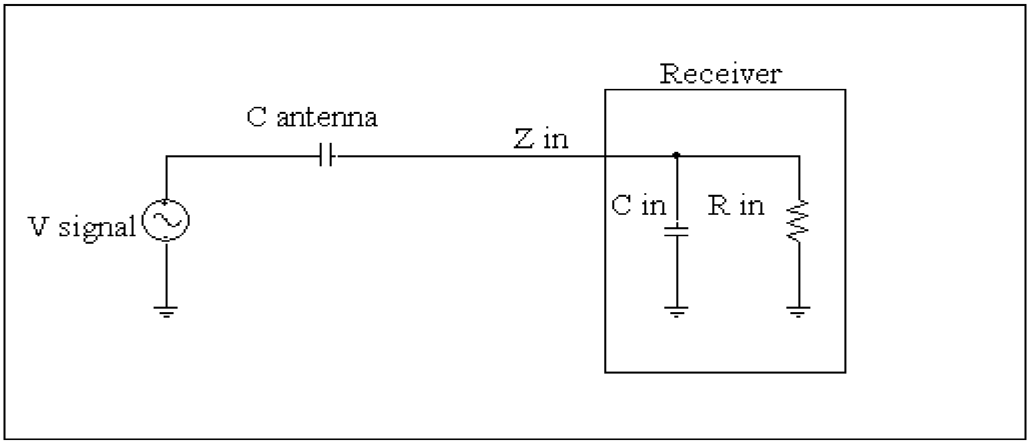
An experimenters approach to detecting the Schumann Resonances

The earth / ionosphere wave guide resonances were first predicted and mathematically described in 1952 by W. O. Schumann, the man who's name is now synonymous with the phenomenon. He also became the first to report in open literature the experimental detection of this phenomenon (1954). Much conjecture has occurred as to whether Tesla was aware of, and able to utilize, the earth / ionosphere cavity resonance. I tend to believe he did not, but that issue continues to be a contentious one. Presented here is a relatively simple means for the amateur experimenter to monitor the Schumann resonances.

The Schumann resonances manifest themselves as spectral peaks in the natural background EM noise levels. Most easily detected are the first 4 "modes" which occur at roughly 7.8 Hz, 14 Hz, 20 Hz and 26 Hz. The signal levels involved fall into the low picoTesla / microvolt range. As the mode order increases, signal strength decreases.

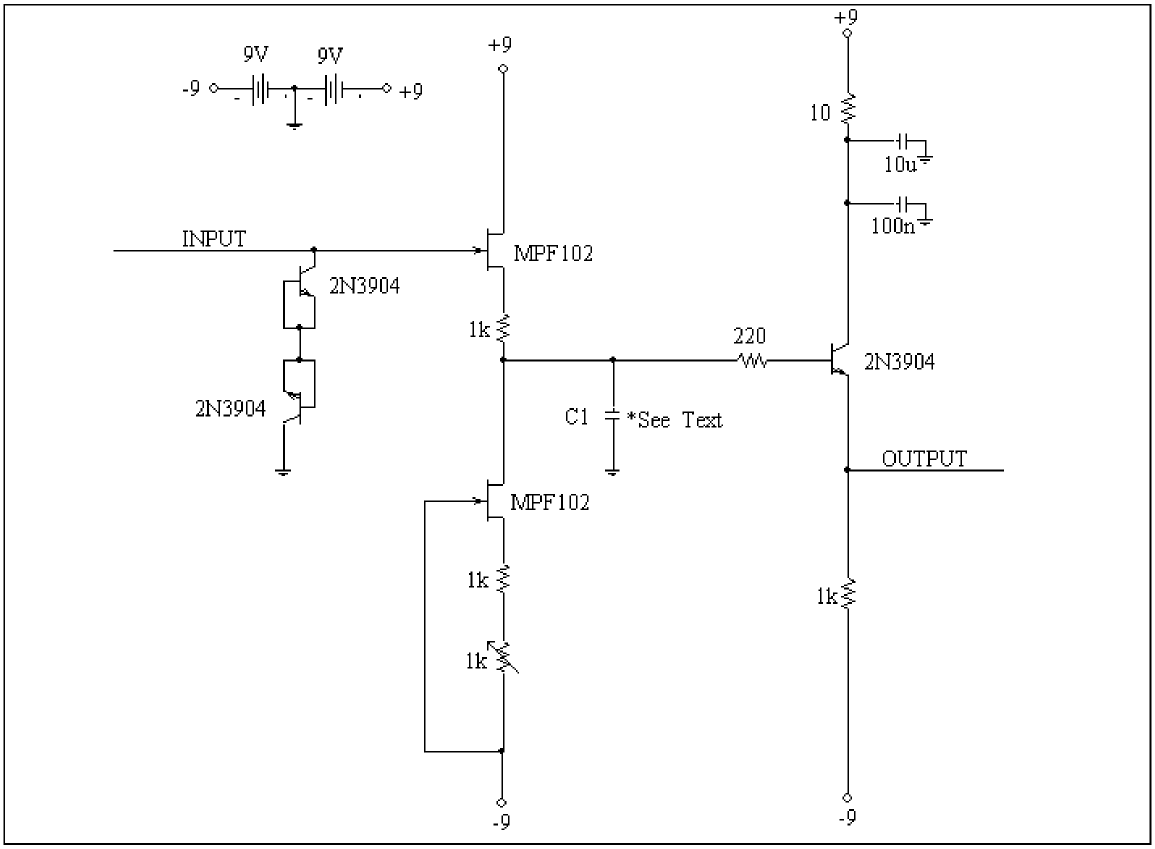
Most "professionals" monitor the magnetic component of the peaks using large induction coils. This method has the advantage of being immune to the ambient weather conditions (the coils are often buried), easy to calibrate and suffering from lower levels of man made and natural interferance. Unfortunately, to have the required sensitivity at the frequencies of interest, the sensor coils must either be physically large in area, contain a huge number of turns or be wound on special very high permeability cores. Recall that the voltage induced on a coil by a time varying magnetic field is $V = \omega ANB$ and the problem becomes apparent. Although this method is surely not beyond the means of ambitious experimenters (see, for example, www.vlf.it/inductor/inductor.htm) it is tedious and potentially expensive. For those having shallow pockets (me), or lacking the resolve to construct such a massive coil (me again), detecting the vertical E-field component of the Schumann resonances gives a workable, if somewhat less robust, option. The hardware is relatively simply and the antenna small, a 2 meter whip.

In the realm of VLF/ELF signals, antennas are always electrically short (< 1/10 λ). In our case the antenna is vanishingly short, 1/4 λ at 8 Hz is ~9400 Km !. Under these circumstances the antenna can be thought of as a capacitor, equal in value to the isotropic capacity of the antenna, in series with a voltage generator representing the signal. The magnitude of this voltage generator will be the product of the incident wave field strength and the effective height of the antenna. A well insulated 2 meter whip reasonably remote from surrounding objects should develop 1 - 10 μV of signal at the first Schumann peak.



Whip antennas posses a theoretical isotropic capacitance of ~11 pF/m. If the signal of interest is at 8 Hz, the source impedance becomes 900 megohms! To avoid loading the signal down, the receiver must present an input impedance that is an order of magnitude larger.

The following simple circuit has been my approach in dealing with such a very high impedance signal source.



Many will recognize it as nothing more than a voltage follower and that indeed is all that it is. It's utility is contained in it's large input impedance which, if some care is taken in construction, should exceed several hundred GΩ shunted by ~10 pF. Fed by the aforementioned 2 meter whip antenna, it will have a flat frequency response from < 1 Hz (yes Hz) to many 10's of MHz (if C1 is left out). It also possesses very low internal noise, excellent linearity and a large dynamic range. Not bad for something that can be built entirely out of Radio Shack parts.

The circuit takes advantage of two things that may not immediately be apparent. First is the fact that although common JFETs are usually only guarantied to have leakage currents of < 1 nA, most are much lower. I have yet to measure a gate leakage current from a MPF102 that exceeds 1 pA at 25 °C. Your mileage may differ, but JFETs are cheap, try another one if success is not to be had. The actual JFET used is not terribly critical. Avoid using "low noise" JFETs advertised for audio applications. These devices achieve their low noise performance at the expense of larger input capacitance and leakage current.

The other advantage is secured by pressing into service the V/I characteristics of a common NPN transistor's base collector junction. If configured as shown, the pair will approximate a very high value resistor. The predicted value for 2N3904 pair is a linear 500 GΩ. In my experience it is not entirely linear and somewhat lower in value ~200 GΩ. This is, however, more than adequate for our purposes. A word of caution, some of these transistors are gold doped which will make them unacceptable for this application but I have yet to encounter this problem. As with the JFETs, these bipolars are very cheap, try some from another manufacturer if you have trouble. As an aside, if you happen to actually have on hand a 10 GΩ, or larger, resistor by all means use it. It will have lower noise and lower capacitance than the bipolar pair.

Construction is non-critical with the exception of a few rules that must be observed.

1) Use a shielded enclosure.
2) Do NOT insert the gate lead of the input JFET into the circuit board, solder it directly to the input connector.
3) Don't scrimp on the input connector. What you use is up to you, but it must have an excellent dielectric. Teflon is best, most other modern plastics are OK. Phenolic is completely unacceptable at this impedance. I use either SO-239 or BNC, both of which are commonly available with Teflon insulation.
4) Avoid touching the input connector insulation or the base of the input JFET. It takes very little contamination to lower the impedance. Clean it with distilled water and pure alcohol if things go awry.

Tune up is simple. Ground the input and adjust the trimmer for zero volts at the output. A few inches of wire inserted into the input should pick up 100s of mV of AC hum and easily detect a piece of charged plastic waved around a few feet away.

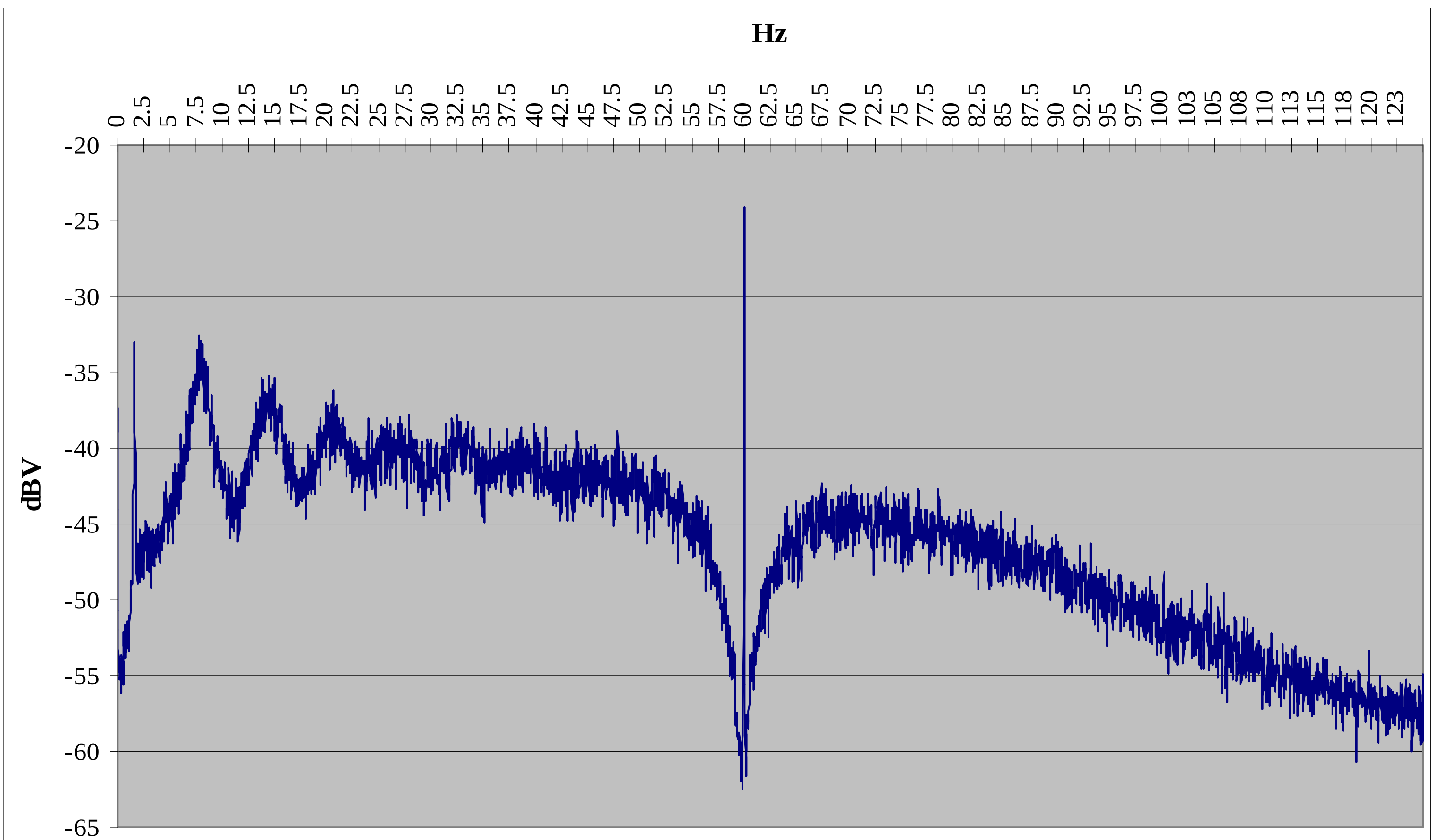
The next problem becomes that of separating the desired signal from various forms of natural and man made interference that will be easily 60 dB or more higher than the signal. Local AM stations, military VLF transmitters, powerful VLF lightning energy and power line interference are some of what must be contended with. Removing C1 and hooking the follower up to a scope, especially with FFT capability, is entertaining. The follower makes a great active antenna at VLF, even with it's unity voltage gain. Anyway, most interference can be reduced to acceptable levels, or entirely eliminated with good low pass filtering. Setting the value of C1 to 270 nF will dramatically reduce the unwanted higher frequency crap. As the circuit is sensitive to frequencies below that which we are interested in, it pays to use some high pass filtering also. Most problematic to deal with will the 60 Hz noise. Sharp low pass and notch filters will help, but this is very dependent on the location. Some folks may find it impossible to remove enough of the 60 Hz energy at their location. The only alternative then becomes seeking a location that is electrically quieter. The actual filter configuration used will be dependent on individual needs.

Last in the signal chain, some amplification of the filtered signal will be needed. The amount used will depend on the device being used to perform the spectral analysis and it's input dynamic range. The amount tolerated will be predicated on the resultant levels of 60 Hz energy after filtering. The output signal must not clip as information will be lost and the FFT will generate bogus data. At my location a gain of 100 seems to be a good all around value.

Finally some means of performing spectral analysis of the signal are needed. This is usually done using a ADC and a Fast Fourier Transform or FFT algorithm. Although once relegated to the realm of high-end test equipment, FFT capability is now common. I use a digital oscilloscope that has a FFT function built in. Less expensive options are now commonly available from companies such as Pico Technologies and Dataq. In fact, as of this writing (8/22/01) I see Dataq has a “start up” kit for $15. It boasts 4 channels with 8 bit resolution at 240 samples per second, certainly adequate for this application (www.dataq.com/cgi-local/SoftCart.exe/115.htm). For those that wish to spend no cash, a PC sound card can and will work with limited flexibility. There are several freeware soundcard FFT programs available.

Choose an antenna location as far from power lines and surrounding object as practical. Nearby objects, such as trees, will form a capacitive voltage divider with the antenna and lower the signal, often dramatically. Monitoring during foul weather will be futile due to wind-induced signals, charge pulses from raindrops and the often badly agitated natural electric field. Don’t forget to ground reference the follower!

The chart below is an example of the sort of data I have collected. Integration time was 40 seconds. Twenty-five samples were averaged to reduce the noise. I use a notch filter at 60 Hz, hence the odd dip in the data.



This paper was written in haste and as such will likely contain errors and also be found devoid of certain details. I am more than willing to answer questions for those that would seriously attempt to duplicate this project. Please address any correspondence to sfusare@adelphia.net