This is a follow-on to my recent posting regarding coupling MW and LW antennas to the Sony ICF-2010. This covers coupling shortwave antennas and consists of two postings. This posting describes the problem and the circuit I came up with to remedy it.
The second posting is an ASCII encoded (uuencode) .gif file containing the simple circuit diagram.

## The Problem

The most serious problem with the Sony ICF-2010 has been well documented over the years and concerns the vulnerability of the RF amplifier transistor to electrostatic discharge. When a 1/8-inch phone plug is inserted into the external antenna jack, any voltage present on the attached wire is ported to the gate of the FET. Most of these transistors have a maximum voltage rating on the order of 40 volts peak. Static discharge from body contact or nearby high impedance fields, such as those caused by lightning can reach hundreds or even thousands of volts. Bear in mind your receiver doesn't have to take a direct hit. A high impedance electric field can induce a destructive voltage along a wire.

Examination of the schematic furnished in the Sony service manual shows that the whip antenna is given some protection with a pair of zener diodes. External antennas designed to protect the receiver's input circuit may be used with relative safety; however, there is still a danger when inserting or removing the plug.

The second problem affects performance. The gate circuit of a FET, such as the RF amplifier in the 2010 is high impedance.
Since the antenna is directly coupled to the gate, the antenna output impedance should also be high impedance in order to provide optimum signal transfer. However, typical antennas, such as dipoles, loops or any antenna having a transmission line have relatively low impedances on the order of 50 to 300 ohms. A long wire will have a variable impedance which is a function of the length of the wire and the frequency. The bottom line is that there is significant impedance mismatch between most shortwave antennas and the receiver.
This prevents the antenna from delivering maximum voltage to the receiver at most frequencies.

The third problem is also one of performance.
It is characteristic of virtually all digitally-tuned portable receivers.
It is the lack of dynamic range.
In the old days, the input circuits were tuned with coils and variable capacitors. As you tuned in a station, a significant portion of the unwanted RF spectrum was filtered out right at the receiver input. To date, there is no easy inexpensive way to do this with a digitally-tuned receiver. As a result, every signal present on the end of the antenna is fed into the receiver.
Once inside, everything gets amplified. Sufficiently strong signals will overload the remaining RF processing circuits and cause effects we know as cross-modulation or inter-modulation. The effects are most noticeable under good shortwave propagation conditions when everything across the band sounds like mush and you hear lots of stations where they are not supposed to be. Most receivers have a so called "DX/LOCAL" switch to provide a modest amount of relief. The Sony approach is typical. In the local position a voltage divider is inserted early on in the circuit to attenuate the incoming signals. An alternate approach is to shorten the antenna. In either case, the signal grabbing power of the antenna and receiver system is greatly reduced.

## The remedy

A solution to these problems involves (1) protecting the receiver's input, (2) improving the impedance match between the antenna and the receiver, and (3) attenuating at least some of the unwanted signal level before it reaches the receiver.

Given the complex tightly packaged receiver design. There is very little the hobbyist can do inside the receiver case. On one of my own receivers, I removed the external jack so that its mere presence would not invite disaster. I had already ruined three RF amplifiers before I fully understood what was happening. Simply removing the jack from the circuit board; however, creates another problem. Two switch closures are made inside the jack with the plug removed. Jumpers must be soldered on the circuit board in order to make the receiver operate with the jack removed. This is an operation which I don't recommend.

My final design, therefore, had a fourth requirement - that no internal modifications be made to the receiver. This further restricts what the hobbyist can do. It leaves the whip antenna as the point of input. Access to the receiver ground can be gained through either of the exposed antenna jacks.

My first thought was to design a pi matching network. These were the tried and true impedance matching circuits years ago. A simple network consists of a series coil with a variable capacitor shunted across the input and a second capacitor across the output. Each time you tune to a new band, the capacitors are tuned to peak the signal.
Peak tuning indicates an impedance match has been found.
Note that this is not the same thing as a resonant circuit.
Simple impedance matching does reject a certain amount of adjacent signal interference; however, not nearly as much as a resonant circuit.

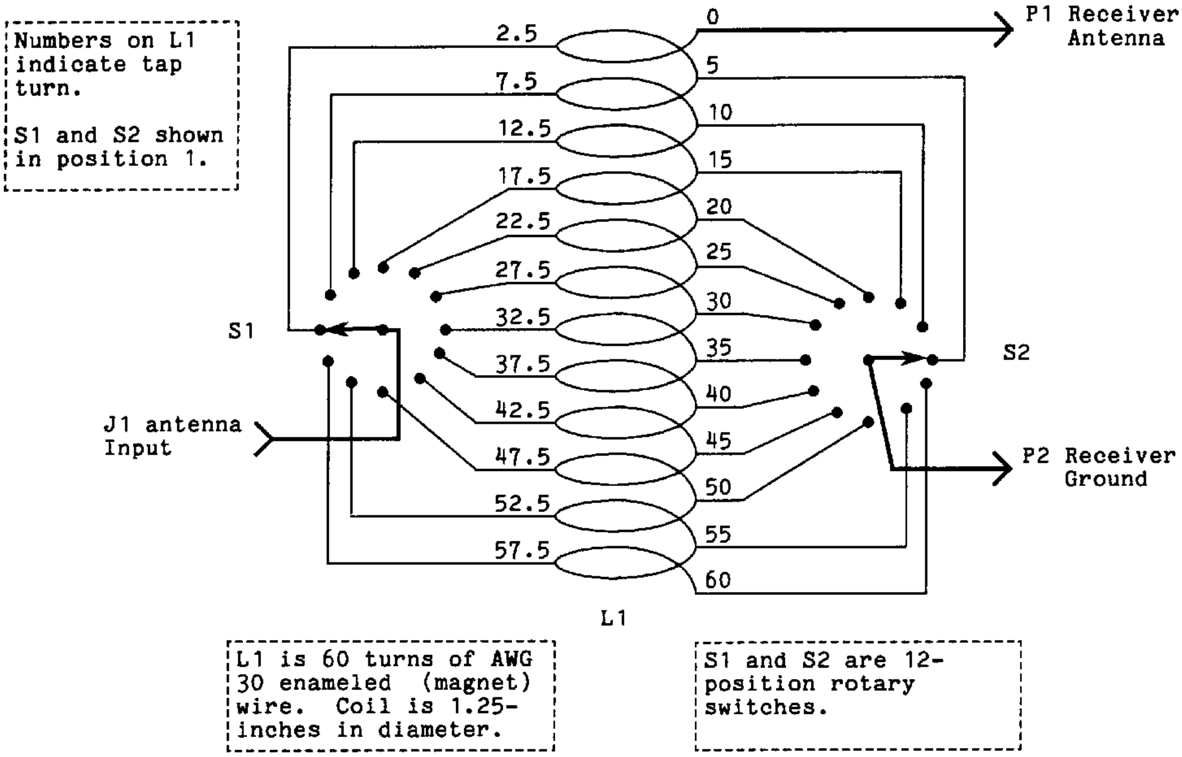
Unfortunately, good variable capacitors have gone the way of the vacuum tube.
Digital tuning has rendered them virtually extinct.
For a while, I was salvaging them out of old radios, but these are generally bulky with respect to modern electronic components and often have to be padded with fixed capacitors to a chieve the correct capacitance range.

To make a long story short, my final design is essentially a variable autotransformer. An autotransformer is an impedance matching device, which, unlike a multi-coil transformer, has only one coil with the input and output using different taps.

## Construction

The circuit has three parts, a coil, which you must fabricate yourself and two commercial rotary switches to vary the input and output impedances. Twelve-position rotary switches (Radio Shack part number 275-1385) are used on the input (antenna side) and on the output (receiver side). The antenna is connected to the wiper of the input switch and the 12 poles are connected to taps along the coil. The wiper of the output switch is connected to the receiver
ground (the outer sleeve of either external antenna jack). The 12 poles of the output switch are connected to different taps along the coil. Turn 0 on the coil is connected to the whip antenna. The table below shows the exact tap connections.

| Switch Pole Number | Antenna Switch Coil Turn | Receiver Switch Coil Turn |
|---|---|---|
| 1 | 2.5 | 5 |
| 2 | 7.5 | 10 |
| 3 | 12.5 | 15 |
| 4 | 17.5 | 20 |
| 5 | 22.5 | 25 |
| 6 | 27.5 | 30 |
| 7 | 32.5 | 35 |
| 8 | 37.5 | 40 |
| 9 | 42.5 | 45 |
| 10 | 47.5 | 50 |
| 11 | 52.5 | 55 |
| 12 | 57.5 | 60 |




The coil is 60 turns of AWG 30 copper enameled wire. Turns are wound tightly in a single layer. The coil has an approximate diameter of 1 1/4 inches. I used an old plastic 35-mm film can as a coil form. Taps are made every 2 1/2 turns as you wind the coil, stripping away about 1/8-inch of the enamel insulation and soldering a 3 or 4-inch connecting wire for eventual connection to the switches. I used the AWG 30 copper enameled wire for the taps to reduce the bulk and stress on the solder connections.

The switches come with a tab which prevents 360 degree rotation.
This should be bent out of the way to permit full rotation and facilitate operation.
The switches should be mounted on either side of the coil in a small project box.
I used a phone jack for the antenna input.
The output leads for the antenna and ground should be kept separated from one another and as short as possible - no more than 8 inches.
Alligator clips can be used to connect each lead to the receiver.
I fabricated a special clip to grip the swivel base of the whip antenna.
The ground connection is tricky.
You don't want to use a standard phono plug, as that will switch the contacts inside the jack and cause problems.
You only need to make contact with the outer sleeve, so a sawed off phono plug might work well.
If you are using a dipole antenna or any antenna requiring a ground connection the input ground can be made to the receiver ground inside the coupler box.

## Operation

Tune the receiver to the desired shortwave band. Alternately adjust the input and output switches until you obtain maximum signal indication on the receiver LED's. The changes in signal level may be subtle, so you should adjust each switch two or three times and note any improvement. There may be two or three switch combinations which produce nearly optimum response.

It is advisable to make a chart of switch settings for each band of frequencies you tune. The chart should have three columns, one for the frequency band and one for each of the switch positions. It is best to determine the optimum switch settings during daylight hours when signal levels are not as strong.

Once you have established the optimum switch settings, they will remain the same as long as you don't change the antenna. If you change the antenna length or type, you will have to determine new settings for the coupler. Generally, the same switch settings will remain optimum over a 200 to 500 kHz band. You will not find a consistent pattern or progression of switch settings as you go up or down the shortwave spectrum. Thus the settings will have to be determined experimentally for each band.

Changes produced by adjusting either switch can be subtle or dramatic. Results, as indicated on the receiver's LED signal strength indicator can be negligible or produce as much as a 4 LED increase over operation without the coupler. Improvement depends on the amount of mismatch between the antenna and the receiver at the frequency being tuned.

Regardless of the gain in signal strength, the coupler will help attenuate out-of-band signals which don't match the impedance.
This results in less frequent use of the DX/LOCAL switch and better use of the receiver's available sensitivity. You might call this better dynamic range, although it is being manually controlled. In some cases, it will be found that tuning the coupler slightly off the optimum signal strength setting will virtually eliminate overload with the DX/LOCAL switch in the DX position. This may produce a more desirable setting.

It is interesting to note that the coupler will also affect FM reception, and, to a lesser extent MW reception. However, the effect is not always an improvement and you may want to disconnect the coupler whenever listening to the MW or FM bands.

Regarding long wire antennas, it has been this writer's experience that anything over 25 feet in length yields diminishing returns, and, in fact, may promote reception of noise or signal overloading. A few simple rules suffice. (1) Keep the wire as high as possible. (2) Avoid proximity to TV sets, computers and other sources of RF radiation and noise. (3) Keep the wire away from metal shields such as aluminum siding, conduit or furnace ducts.

Good Dxing

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