Transmission Line Signal Sampling

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When I was finalizing the mechanical layout of my remotely-operated 3-position coaxial antenna switch (Fig. 1), I wanted to include a way to bring out a sample of the signal being sent to the antenna. This would provide me with a convenient point to connect an oscilloscope, a spectrum analyzer, an rf voltmeter or a lab-quality power meter. The signal sample would be taken from the center conductor of the coaxial cable and the sampling ratio, for my application, should be known, constant, and repeatable.

Three methods of obtaining this rf sample were considered: (1) by induction from a wire physically near, and parallel to, the center conductor, (2) from a resistive or capacitive voltage divider physically connected to the center conductor, or (3) by transformer coupling from the center conductor. See Fig. 2.

The degree of coupling in Method 1 is highly frequency dependent and difficult to predict and control in this application. Bird and others precisely control the coupling between the two wires in their wattmeters to provide power readings with a reasonable degree of absolute accuracy. SWR meters can use this method because they sense the voltages at either end of the same wire (or two identical wires), and use the ratios of the voltages thus eliminating the need for absolute accuracy.

Method 2 is simply a voltage divider and is the easiest to implement. It doesn't matter if the divider circuit is constructed from capacitors or resistors, although resistors are usually the component of choice. The resistors must be noninductive in order for the sample to be independent of frequency. Some of the transmitted power is sacrificed in the divider circuit, and the resistors must be capable of dissipating this.

Method 3 relies on the turns ratio of a transformer. The transformer typically uses a high-permeability ferrite toroid core and the center conductor of the coax passes through the center of the core to form a single-turn primary "winding". The number of turns in the secondary winding determine the sampling ratio. The load connected to the secondary is reflected back to the primary as the inverse square of the turns ratio, so there is some small amount of transmitted power lost. The transformer also provides dc isolation offering some protection for that magical moment when a failure in a power amplifier sends 2,400 volts down the coax center conductor.

Ok, now what? I decided that a sampling ratio of 30 dB, providing a power ratio of 1:1000, would be suitable. Thus, 1 kw in the transmission line would yield a 1-watt sample, and 100 watts would provide a 100 mW sample. A 30 dB or 1000:1 power ratio is a 31.62:1 voltage ratio. The sample should be delivered from a source impedance of 50 ohms or less. The instrument connected to the sample port should have an impedance of 50 ohms or more.

Given all of the above, Method 1 is discarded. Method 2 requires a series resistor of about 765 ohms. The power dissipated in that resistor is about 6 watts for a transmitter power of 100 watts and about 61 watts if the transmitter power is 1000 watts. Assembling noninductive resistors to achieve that resistance and dissipate that much power isn't a trivial undertaking.

That leaves Method 3. The secondary winding needs to be 31 turns on the toroidal transformer core. Each passage of the wire thru the center of the core is 1 turn, so the theoretical 31.62 turns isn't possible. I used 31 turns of #28 enameled wire on a FT-50-75 toroid. The completed coupler is shown in Fig. 3. It is made up of a piece of #16 solid wire slid thru a piece of RG-8X dielectric slid into a piece of 3/16" brass tube which is covered with 3/16" shrink tubing. This assembly goes thru the center of the toroid. The brass tube is grounded at one end. The #16 wire becomes the coax center conductor and the brass tube is the shield. The intent is not so much to simulate a 50-ohm transmission line, but to have a 30 dB coupler without capacitive coupling or arcing.

Figure 4 shows an alternate method of construction. Here I used 31 turns of #22 wire on a FT-82-61 core. The core is placed over a piece of RG-8 coax approximately 2" long. The coax shield is grounded at one end to serve as a Faraday shield. The finished product is housed in a small aluminum box with SO-239 connectors for the coax and a BNC(f) connector for the sample.

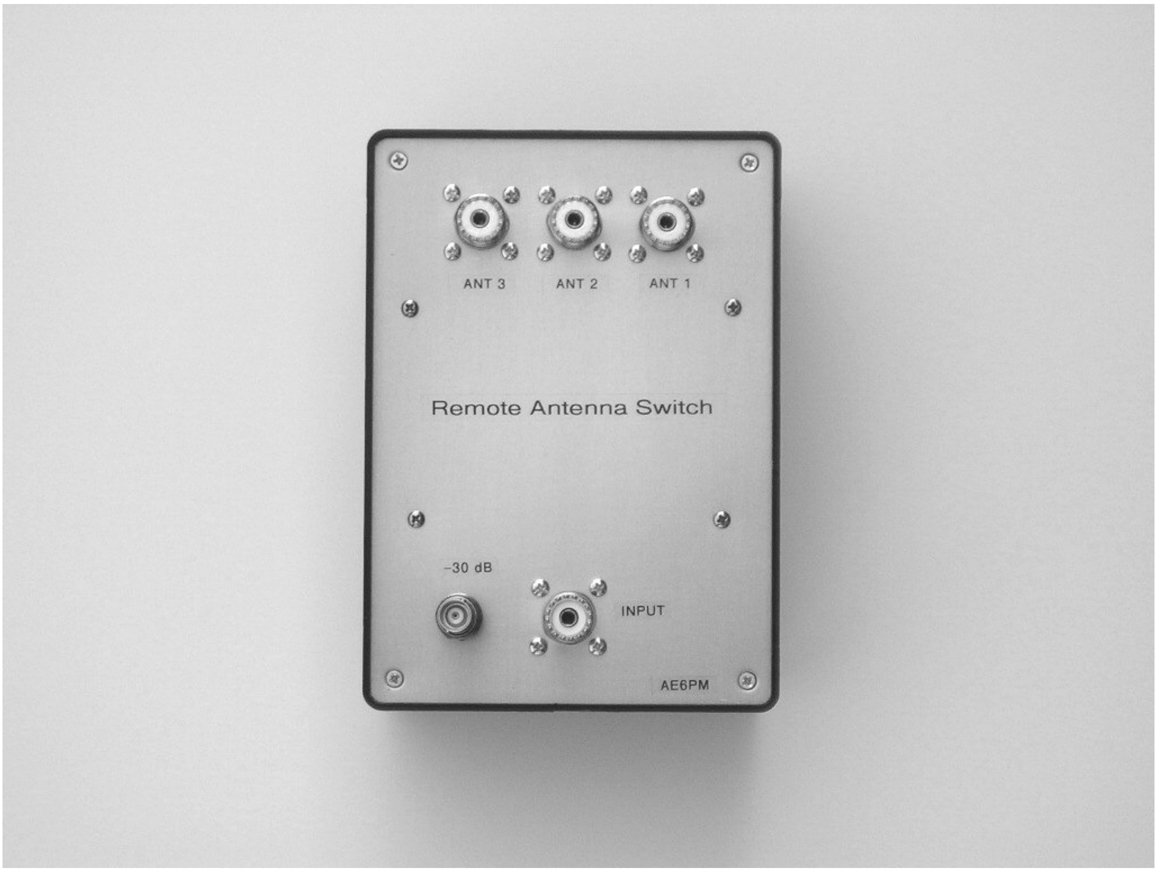

Fig. 1 – My remotely operated 3-position coaxial antenna switch.

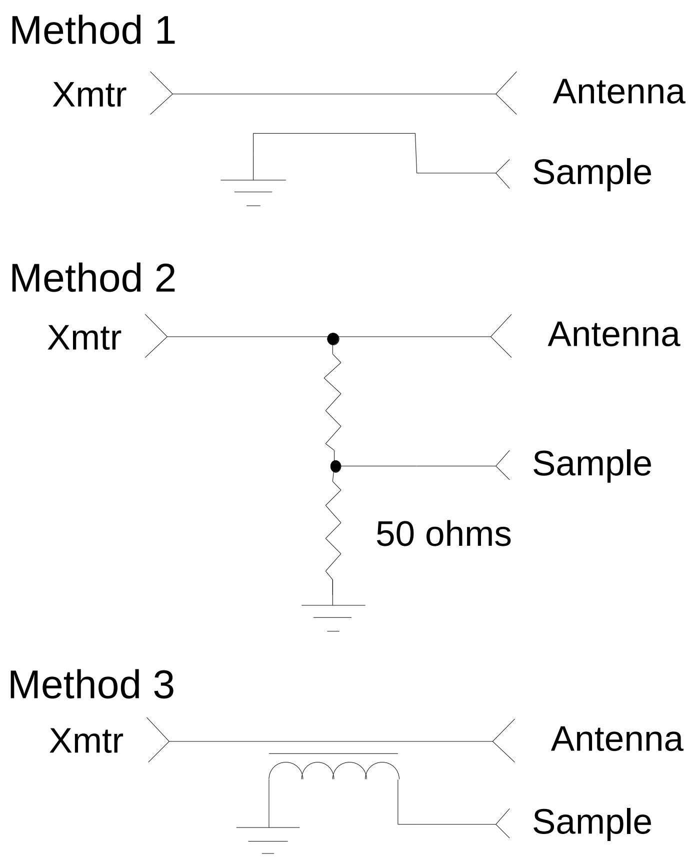

Fig. 2 – Three methods for obtaining an rf sample from a coaxial transmission line.

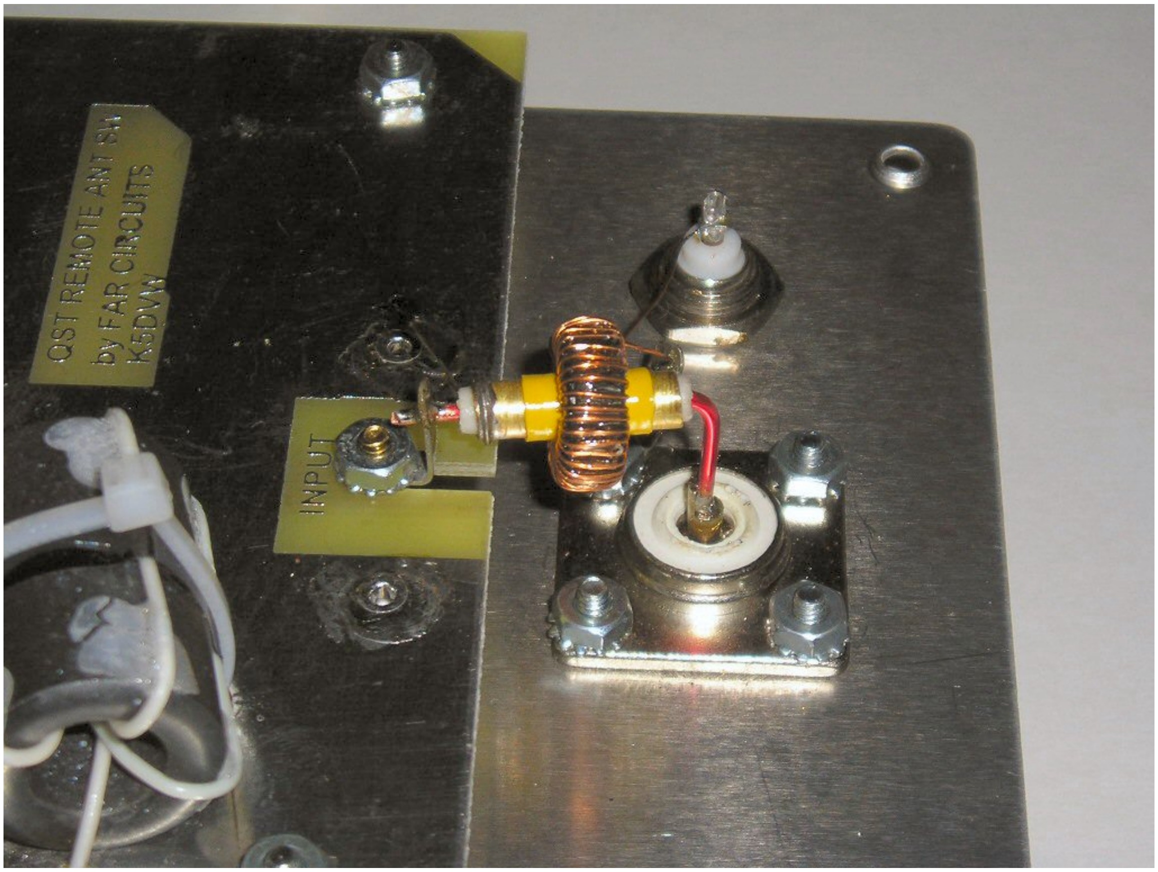

Fig. 3 – The 30 dB coupler as built into the antenna switch.

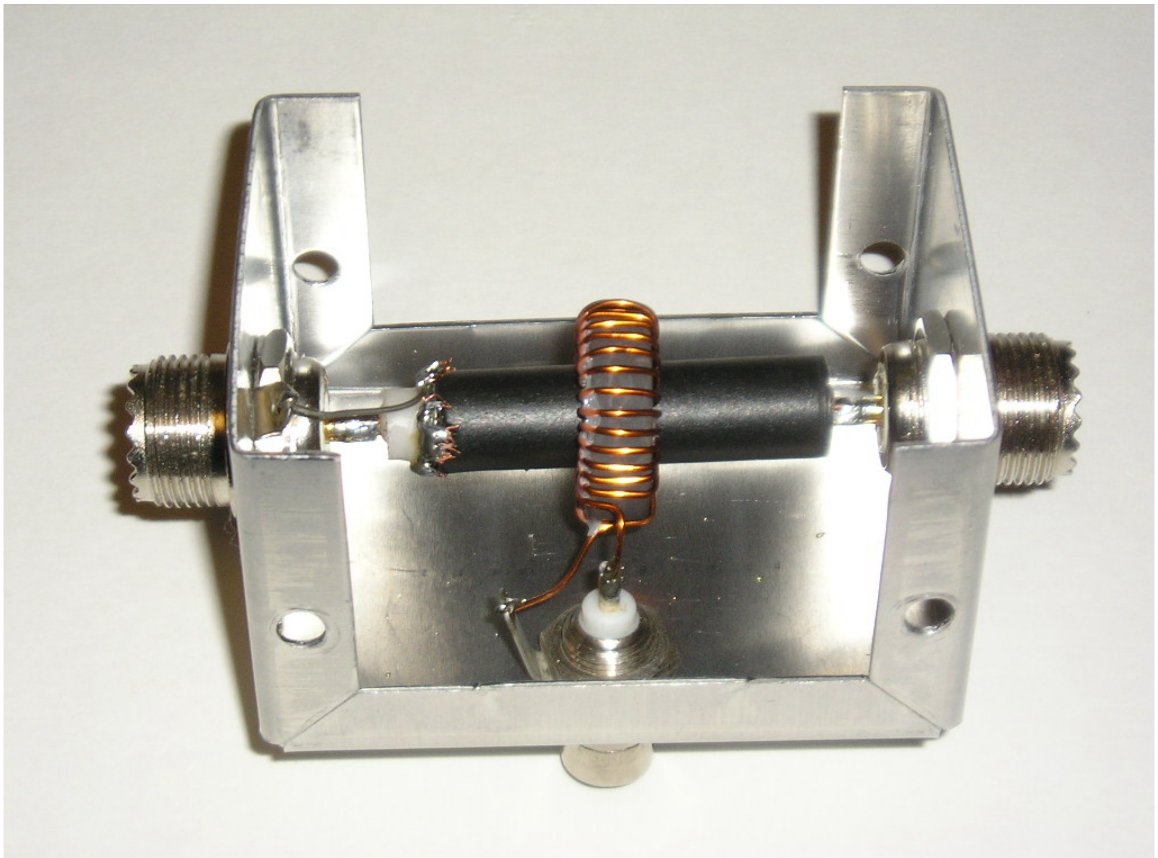

Fig. 4 – A 30 dB coupler packaged as a stand-alone test aid.