Above & Beyond

VHF and Above Operation

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Surveying the surplus coax switch

This month, I want to get into the subject of coaxial switches and different types of RF switches in general. As you know, an RF switch is, electrically speaking, nothing more than a simple toggle switch activated by either a mechanical motion or a solenoid relay action. This motion, either electrical or mechanical, is used to transfer the contacts from receive to transmit in normal applications.

For low frequencies, the task can be performed by an open-air type of switch mounted in a suitable metal container equipped with coaxial connectors. Wiring at low frequencies is not critical. Going to the extreme in low frequency operations—say, in the 1 MHz area—the entire operation can be accomplished with long wire leads and a suitable manual switch. In the very early days of amateur operation, this was just the method used to switch an antenna from transmit to receive or between different antennas. It was inexpensive, available, and it worked well.

Today, most of the RF switching is taken care of with solenoid-operated switching devices. These devices started to show up in designs before World War II. I tore apart many different surplus military transceivers and high power transmitters to obtain parts to use in my early amateur construction projects. Not having won the lottery, nor having deep pockets, I had to be frugal in my radio ventures and thus used these surplus resources to the max.

I can remember dismantling ART-13s, ARC-5s, and other HF units, as well as VHF counterparts to the ARC-5 line and even some military surplus cavity units in the low frequency microwave area of 1000 MHz. This surplus material left me with a wealth of component parts, as well as experience in stocking a large junk box for

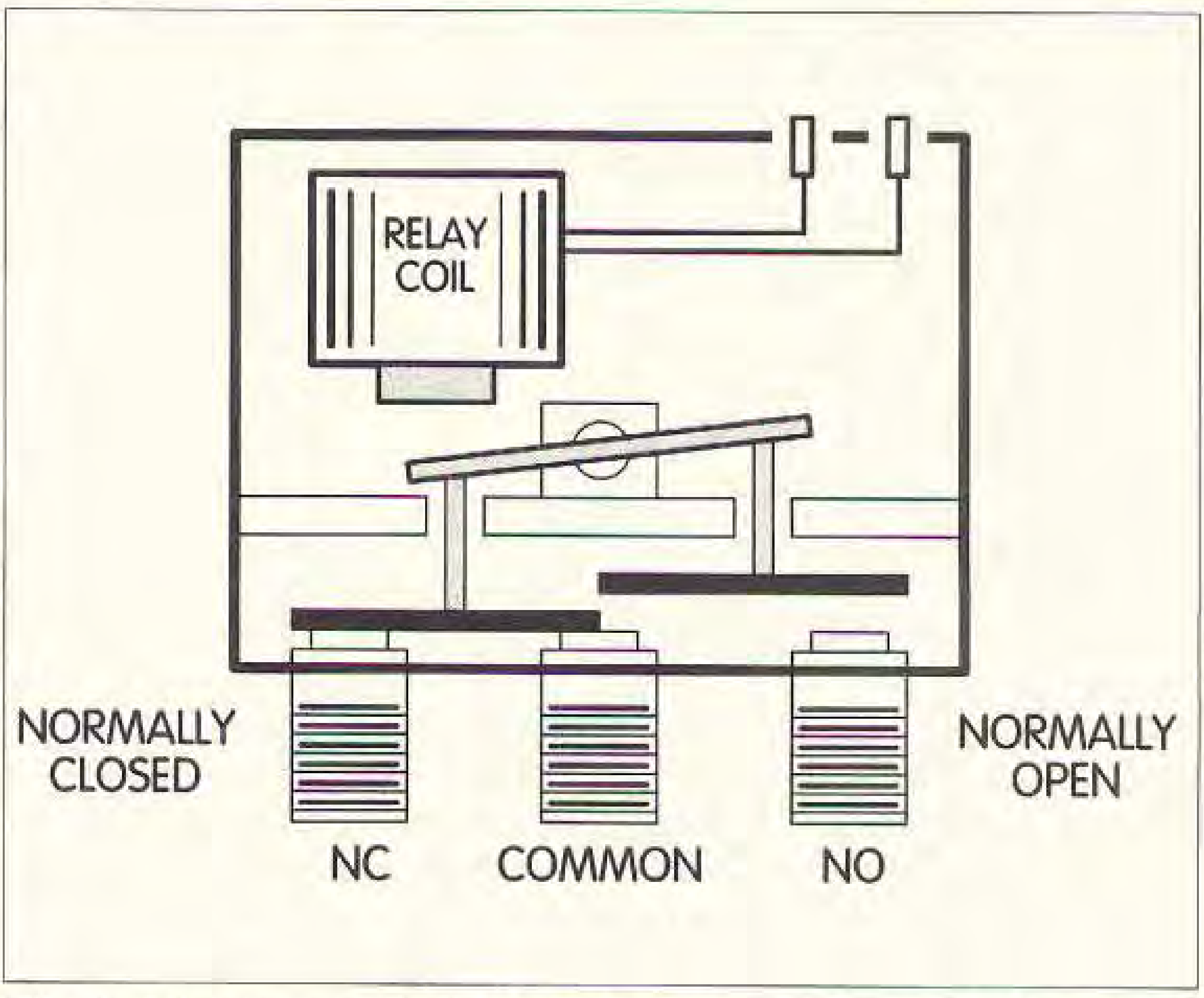

Fig. 1. Microwave switch internal construction. Note balanced actuator arm that pushes bar contact from grounded out-of-circuit position to contact from one side of switch to center contact. Left or right side of switch operation identical. Typical frequency of operation from VHF to 24 GHz. Size of switch decreases to reflect increases in frequency.

construction projects. Material scrounged included tubes, fixed and variable caps, resistors, and any RF switches I could find.

Well, since I was quite smitten by VHF operation in those early days and they were within my price range, I salvaged the best coaxial relays I could obtain from these surplus sources. The switches I used were not ideal but they *were* on hand. They were full coaxial, except for one terminal which was a solder-lead type. Surplus being what it was, that was how it was used in the VHF ARC-5 radios I pulled the switch from. The relay was external to the metallic enclosure, and operated the armature which pushed an insulated bar into the box to transfer the function of the enclosed relay contacts. It was not ideal, but for surplus prices in the early '60s it worked well until something better came along.

The real primo coax relay was a Dow Key. It was much sought after, if you could afford one. The only other alternative was a glass vacuum RF switch that was removed from the high power HF military surplus radios. I never used these in VHF operation, but know now that in suitable enclosures they work quite well. In those early days, we did the best we could.

Today we have so many choices with commercial equipment—and not much relief in price unless you scrounge the surplus markets and swap meets looking for material. If you want quality and want it now, you have to pay for it. If you can assemble a shopping list and be willing to do some trading or swap meet looking, it will come your way eventually. It just might take a little time to fall into place.

What are your choices and what relays are the best for you? Do you even need a coax relay, since most of the transceivers packaged today provide all switching needed in a basic transceiver for HF or VHF/UHF operations? What can you do to evaluate just what is right for your situation? Well, the answers are not simple, as a little background material is needed to get you up to speed on what is required for a frequency by frequency and power level type of approach.

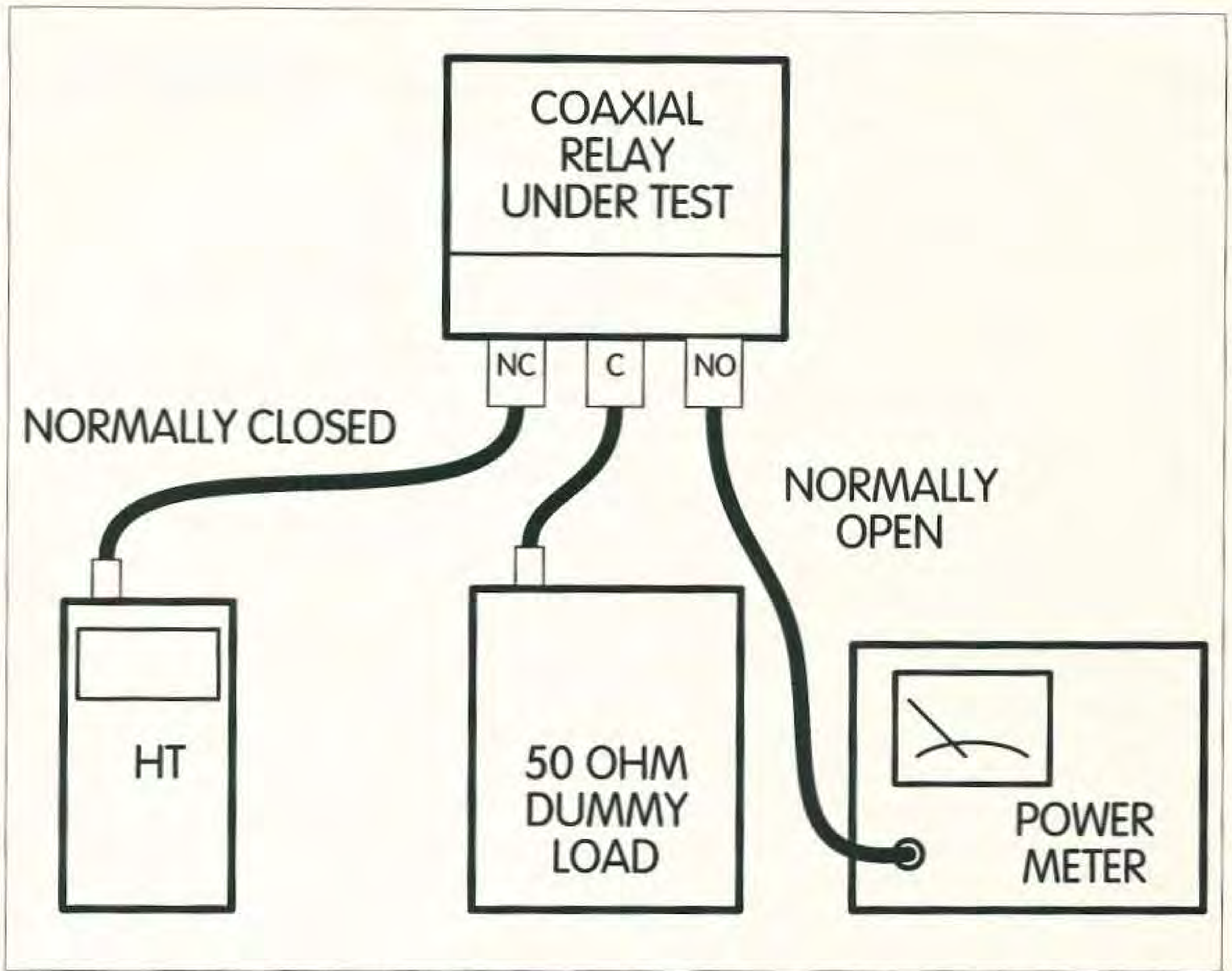

***Fig. 2.** Test setup to measure isolation between switch ports. Signal generator (transmitter) places power through contacts of switch. Power measurement made at open switch contact to verify isolation of switch. Isolation should be better than 50 dB for a good switch.*

To start to evaluate coaxial switches in general, you first need to lay out just what you want to switch and list the frequency and power level involved (as everything changes as you get higher and higher in frequency). As frequency increases above 1,000 MHz, things get downright mean in what it takes to perform well. Also, power handling capabilities decrease as frequency is increased.

What is going on internal to the relays is much the same as with construction practices used at similar frequencies. At low frequencies such as 80 and 40 meters, open wiring with no particular attention to wire dress or position is required. (Look at antenna tuners, for example, to see what is allowed at a particular frequency.) As we get into 20 to 10 meters, it starts to get fussy with regard not only to lead dress but also the length of wire used to make connections. At 6 and 2 meters, connections used at lower frequencies will be called RF chokes and actually impede the flow of RF. On 6 and 2 meters, very short connections are a must.

As we get even higher in frequency, the components used in construction of a switch start to take on a very large fractional portion of a wavelength in physical size. When the dimension becomes large, the switch elements tend to radiate the energy they are trying to switch. In these devices, special precautions must be taken to eliminate cross coupling between unused switch positions and other parts of the switch. At low frequencies such as 1 MHz, these cross coupling questions are just as important, but due to the very long wavelengths involved, construction lead length is not critical.

What, then, constitutes good construction of an RF switch for modest power levels that will function at HF through 450 MHz? Let's examine what is offered for sale today and take a look at the internal structure of what makes a good manual switch.

What is a manual switch? Well, there are several being offered for sale today. Physically, the basic switch has one input and one connection path out and a switchable alternate path. SPDT—Single Pole, Double Throw—is the most common one.

Switches from military or commercial surplus include multiple outputs just like the Transco manual switch I described earlier. Most common types I see on the surplus market have 24-volt relay coils, SMA miniature connectors, and are intended for UHF through microwave frequencies. The miniature multi-output types are not rotary in operation but instead use an individual relay for each contact selected. The relays shown in **Fig. 1** are of the type I use at 10 GHz. The switch is about the size of a large postage stamp. Others similarly constructed (but much larger by a factor of about ten) use type-N connectors and work at lower frequencies and higher power levels.

For HF operation, a home-constructed switch might take the form of a heavy-duty ceramic rotary switch with contacts that are about 1/4-inch in diameter. Additionally, the ceramic switch spring is constructed out of several layers of spring material and backed up with a heavy brass or plated-steel armature for the switch contact rotary section. This type of switch is typical of a surplus heavy-duty RF switch removed from older military surplus. Usually it is so heavy it must be mounted on a panel in order to operate the manual switch from one position to the other. It switches into position with a loud "snap" sound, making very evident it switched.

I would hesitate to use this type of switch above 20 MHz and rate it iffy at best near that frequency. An improvement would be to mount the rotary switch in a metal box and fix connectors for each switch contact. As you look inside the metal box of such a switch and its wiring, you can see that there is a certain amount of coupling between each section of the switch. In other words, there is still some coupling (poor isolation) between sections of the switch that are in proximity to each other. Think of the operation as coupling between a tangle of clip leads scattered on your workbench.

To test this isolation, you just run a test signal through the closed contact path and test at the open contact to see how much of the signal leaks through to here and its connecting leads (see **Fig. 2**). What you want to see is lots of isolation and very little signal leaking through. The measure of the loss is the rating of isolation, usually expressed as dB isolation. In this simple switch loss is low, giving it a poor rating above 20 MHz because of poor isolation as frequency is increased above a point. Operation at lower frequencies is quite proper.

The reason you want high loss between the switch contacts is that a transmit path might have 100 watts of power going to the antenna. The open contact is the receiver, and if the isolation is poor, an appreciable amount of power will be coupled into the front end of the receiver. This is not what we want to happen. With a receiver sensitive to minus 100 dB and transmitters with output powers in the 100 watt category (+50 dB), it is safe to assume that a great switch would have isolation in the 50 dB or better range to protect the equipment (receiver) it is switching.

Coupling (poor isolation) is the bane of any coaxial relay circuit. If the frequency is low, the extraneous wiring can be tolerated because the wavelength at these lower frequencies is quite lengthy and short hookup wiring techniques are tolerated. As the frequency rises, shorter wiring methods must be used to limit excess wiring and its associated coupling. All is not lost, as there are switch layouts that help to minimize coupling between switch elements and make them virtually invisible to each other.

What layout can we use to provide low coupling or high loss between adjacent elements of the switch? Well, when we think it out, it can be shown that the best switch would duplicate as best it could a manual coaxial connection. The switch would look in this scenario like a manual coaxial switch panel. The switch panel is one that is entirely made up of coaxial connectors and one patch cord (coaxial). When you wanted to select a new port, you would have to unscrew the connector and move the cord to the new port connector. Not very practical, but very efficient in minimizing coupling and effecting very high isolation, which is excellent.

What is needed is a mechanical contrivance that duplicates this action to obtain the very best in isolation and at the same time maintain almost zero coupling between ports—just like the previous coaxial connector-and-cord scenario. I am not dreaming, as some of you might suspect by now, but rather I am just trying to make you aware of what is going on and how important isolation can be.

The switch that conforms to this design principle is made by Transco. Its operation is exactly what was previously described in a manual-patch cord scenario. The switch I tested has manual operation and six possible output ports. It exhibits all the quality of the coaxial connector-and-cord operation in a very compact rotary coaxial switch. It uses a spring contactor coaxial hairpin, allowing contact in a coaxial environment with only one contact between the selected main input/output connector. To switch it to another position by manual rotary action, it has a cam action to unseat connections before reseating into the new selected position.

There is virtually no coupling between the main and unselected switch ports, due to the excellent shielding between master and selected rotary contact all done in a coaxial environment. This minimum coupling is accomplished by this cam-operated coaxial hairpin internal to the switch. In all respects this hairpin is just like unscrewing a connector and transferring it to another connector.

As far as isolation goes, the other connectors might as well be in the junk box as you cannot see them with this type of mechanical contact switching. The other unused connectors are out of the picture, electrically speaking. The selected path and its connector are totally coaxial and shielded from everybody else.

The Transco switch is quite robust; I have used it to 450 MHz with no problem. This switch must be bolted to something sturdy, as it does require a few pounds of pull to rotate the switch. You need this hard mounting in order to turn the switch by hand. It has quite a stiff cam action and produces a sharp "snap" sound (of the kind mentioned earlier) when the coaxial hairpin is reseated.

The relay that I show in **Fig. 1** and use at 10 GHz is quite small and uses miniature SMA coaxial connectors. The coax cable that is used has Teflon™ insulation and relatively low loss at these frequencies. As you can see in **Fig. 1**, when the relay has current flowing through the coil it attracts the armature to the pole piece on the coil. This activates the armature in a teeter-totter type of function and uses insulated push rods that raise one end and lower the other end of the switch contacts.

The unused switch contact is pulled toward the top of the switch's enclosed chamber and grounds out on top of the switch compartment. The other element is pushed into contact with the previously open contact and the center main contact. The process reverses when relay current is removed. The internal compartment where this switching action takes place is much like a very short section of air dielectric coaxial cable with the exception that its internal dimensions are square and the impedance is 50 ohms. The impedance is determined by the ratio of inner to outer conductors.

Think of this inner-to-outer ratio as quite similar to the ratio between coaxial cable and its inner and outer conductor. The action is quite the same. When the switch duplicates as closely as it can the coaxial environment and the internal elements are a fraction of a wavelength at the frequency of interest, it will function well. 73

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Radio Direction Finding

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Low-cost monitor for the NorthScope

"Is that radar in your car?" I'm not surprised when visitors to the starting point of our hidden transmitter hunts (T-hunts) ask that question. The lingering yellow glow of the lines on my cathode-ray tube (CRT) display are reminiscent of radar scopes in pre-computer times. But these lines are signal bearings, not aircraft tracks.

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