Build this antenna switch with power-and-SWR meter for the HF bands

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Domestic harmony was the motivation for this project. Our house contains two hams, one of whom is messy and experimental (me).

Before I finished this project, typically, my wife would discover that she could not join her favorite net (the ANZA net, daily at 0515 UTC on 14.183 MHz) because her favorite radio was not connected to anything as a result of me fooling about, and a total mess of cables had to be sorted first. Something needed to be **done.**

This article is essentially a design study, because every ham station will be different in terms of its switching needs. Hopefully, the principles outlined will assist those who want to build an antenna switch to make a station that is easy to operate.

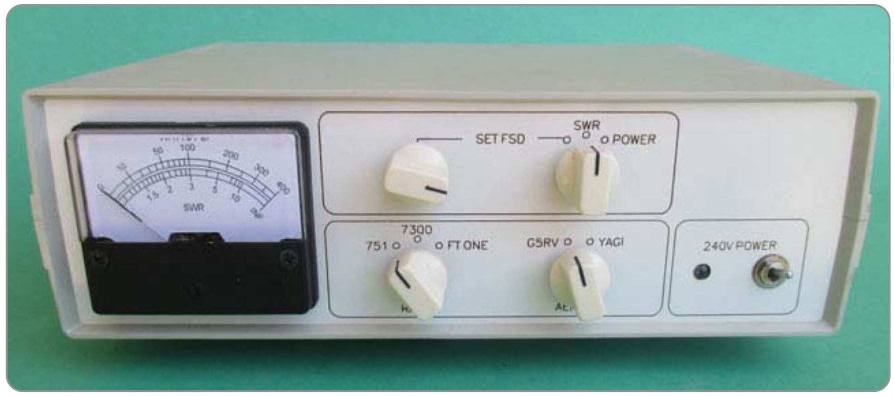


Photo 1: I housed my antenna switch project in an ABS plastic case, 260 x 190 x 80 mm (width, depth, height). I replaced the front and rear panels with 3 mm-thick melamine coated MDF to suit this project. Either operator at this station can select any of three transceivers to connect to either the G5RV multi-band HF antenna, or the Yagi HF beam. Domestic bliss prevails!

Design goals and ground work

I had two fundamental goals: that the switching unit would operate over the HF range and at power levels of up to 400 watts.

Now, in a 50 ohm system, 400 watts creates a voltage of 141 Vrms at a current level of 2.83 amps. Hence, relays or switches designed for 250 Vac mains operation would probably be OK.

Next was the most important consideration of **isolation between radios**. How much isolation was needed to protect the input of an inoperative radio from the output of a radio running at 400 watts? Interestingly, I have never seen any amateur radio equipment manufacturer publish a maximum input to their receiver beyond which damage will occur.

Experimentation showed that the best isolation which could be obtained across a set of open relay contacts was about 45 dB at 30 MHz, due to the stray capacitance of the relay's structure. Now, 45 dB down on 400 watts is 12.65 milliwatts, or a voltage level of 795 millivolts in 50 ohms.

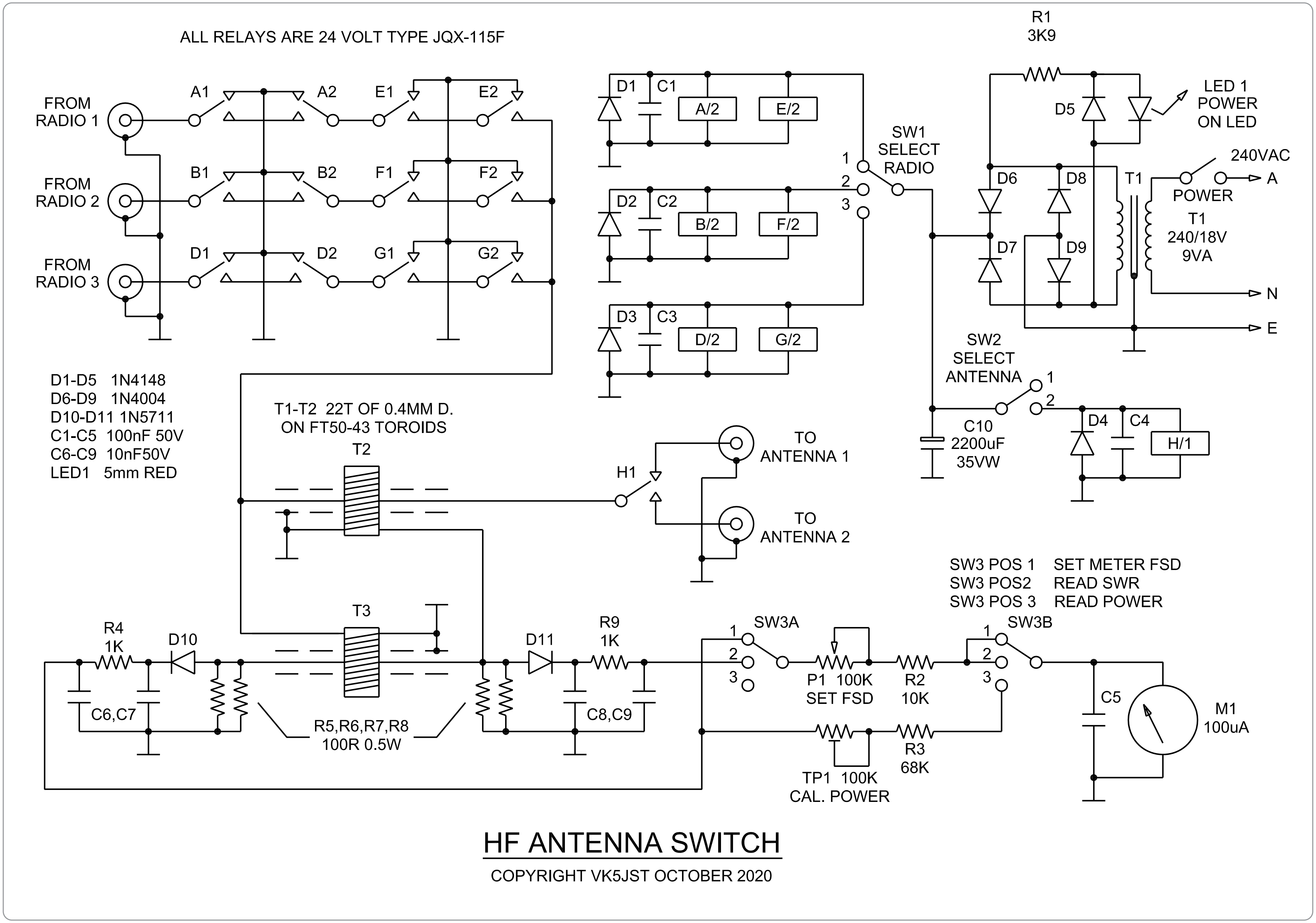
Given that one of the tests on any 'good' receiver is blocking and intermodulation – testing at an input level of 100 millivolts RMS into 50 ohms (-7 dBm), a 795 millivolt input (~0.8 V) to such a receiver is probably easily survivable without damage occurring. This thought is backed up by the maximum safe input level allowed on many spectrum analysers (essentially, wideband receivers) of typically 1 volt RMS.

It is also worth reflecting that the maximum power dissipation allowed in the base-emitter region of any small signal transistor is about 25% of its specified collector dissipation. So, a 300 milliwatt device like a BC108 can safely dissipate around 75 milliwatts in its base-emitter junction, meaning that this power level can be safely tolerated by the first semiconductor in a receiver structure. FETs can typically tolerate around 5 volt swings on their gates, too, and so a picture forms of 1-2 volts RMS being a safe maximum level at a typical receiver input.

None the less, 45 dB of isolation provides a very small margin of safety, and considerably better levels of inter-channel isolation are desirable.

I set 65 dB as my design goal, which translates to an input power level of 126.5 microwatts, or 79 millivolts into 50 ohms, which is still a huge signal, but SAFE.

Note that such a target for inter-channel isolation thus demands at least two sets of contacts in series in the switching, and, as I wanted to take no chances with an unreliable relay misbehaving (say, contacts sticking), and consequently blowing the front end out of an expensive receiver, this meant using two relays in series for safety. If one relay could



Antenna Switch circuit.

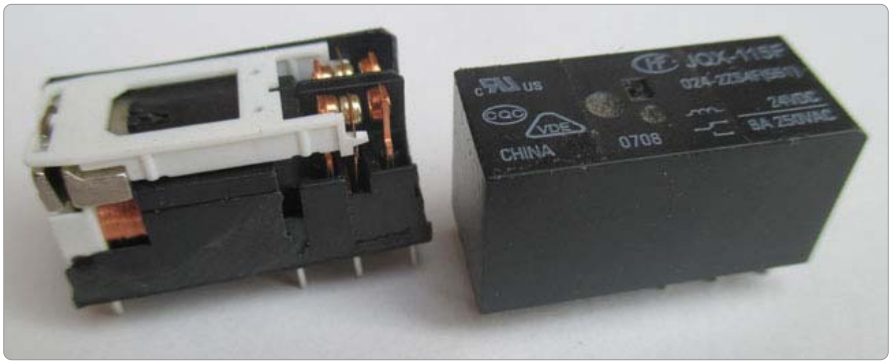


Figure 1: I used these PCB-mounting relays, designed for switching 250 Vac.

fail and on the figures above, there should still be no damage.

As an added precaution, relays with dual contact sets were used, with unused contacts being grounded. This reduces massively the signal leakage across a set of contacts, with the inter-channel isolation now being largely determined by stray coupling and grounding in the printed circuit layout.

So. What relay to use? Over the years, I have collected a huge assortment of relays. Scratching through my junk box produced a number of possible candidates.

Having removed the case from several relays with a bench grinder, I finally settled on a readily available unit, type JQX-115F. This is shown in Figure 1. Note the heavy duty contacts on short vertical support arms. The self-inductance and stray capacitance of the relay contacts are thus very small. The relay contacts are rated at 240 Vrms at 8 amps.

Measurement shows the contact gap is 0.4 mm. Air has a breakdown voltage of around 3000 volts/mm at sea level, which means the flashover voltage for these contacts should be around 1200 volts, and Megger measurements confirmed this. The contacts actually withstood 2000 V with no flashover, probably due to their beautifully rounded shape.

Consequently, there is a substantial safety margin when operating at 400 watts in a 50 ohm system (141 Vrms, 2.82 amps). These relays are available with both 12- and 24-volt coils; I chose the 24-volt version. If you happen to have the 12-volt version available, then the power supply in the project will need modification.

Achieving 65 dB interchannel isolation

Another design goal was to use a cheap plastic case (Altronics H0482, 260 x 190 x 80 mm). I have a cutting laser, and by replacing the front and rear plastic panels with 3 mm-thick melamine coated MDF, I can easily cut out both panels and all holes, as well as engraving all labeling.

But a plastic box would mean that all RF areas would have to be carefully screened to prevent RF leakage into the ham shack.

This is achieved by laying out a double-sided printed circuit board (PCB) to just fit inside the back panel of the case, with the top of the PCB having an extensive ground plane. Interconnections on the PCB bottom between relay switches are done with 50 ohm strip lines, ensuring that the switch exhibits low SWR.

Radiation from the rear of the PCB into the ham shack is prevented by using a second ground plane in the form of a solid metal sheet to which the rear of all antenna sockets (SO-239) are bolted, shown in **Figure 2** (on page 25). Of course, if a metal case is used, this second ground plane is not required.

Construction is easy, because the PCB can be used as a drilling template for both the rear panel and its associated sheet metal ground plane. So, all RF is essentially confined to this big PCB and the associated ground plane, which makes up a closely-spaced sandwich structure. The end result is at least 68 dB of isolation at 30 MHz between the two closest, physically adjacent channels.

The optional RF power and SWR meter

This structure uses the "Stockton bridge" as its basis, which is the only VSWR/power measuring circuit of which I am aware that does not require tweaks and fiddles to set it up. It is one of the many bridge designs created and patented in the 1950s by Warren Bruene W0TTK of the Collins Radio Company.

Its design is simple. Take a look at the lower lefthand side of the circuit. The current in the 'single-turn' primary of the current transformer, **T2**, is 2.82 amps at an input power of 400 watts. After a bit of back and forth, I settled on 22 secondary turns on an FT50-43

*The circuit is quite straightforward. The power supply (top right) is a conventional capacitor input full-wave bridge rectifier to power the relays (and the Power On LED!). **The power transformer** is a common PCB-mounting model, with 240 Vac primary and two 7.5 V secondaries, connected in series. A **Stockton Bridge** circuit, at lower left, samples the transmitted RF passing between the transceiver and antenna. The FT50-43 toroids are widely available (e.g. Minikits). **Switch SW1** selects which transceiver you are using, while **SW2** selects which of two antennas is connected to the transceiver in use. **Switch SW3** selects the operation of the VSWR/Power metering circuit. **Potentiometer P1**, operated by the front panel knob for "Set FSD", sets the full-scale meter deflection when reading VSWR. **Potentiometer TP1** – a trimpot inside the case – is used to set the meter reading when calibrating it for reading power.*

Photo 2: All the antenna and transceiver sockets are mounted to the rear panel, with the "switching magic" happening behind it.

toroid. This gives the largest output voltage possible (swamping the turn-on voltages of D10 and D11), without over-dissipating the bridge load resistors R5-6-7-R8.

The secondary current is 2.82/22= 128.2 mA, giving an output voltage of 6.4 Vrms across the 50 ohm bridge loads at 400 watts. After detection, this gives about 8.9 Vdc into the meter circuit.

To calibrate the power meter, use a non-inductive 50 ohm load with a peak responding detector and multimeter, as described in my article in *AR* magazine No.2 – 2020, pages 35 to 37 *(Simple dummy loads for rig testing at HF and higher frequencies)*.

Note that, if you wish to just use the switching functions of this project, then the RF power and SWR circuits can be easily bypassed on the main PCB by using a coaxial cable jumper. Also note that, if you include this feature, the bridge structure needs careful screening to prevent RF in the shack.

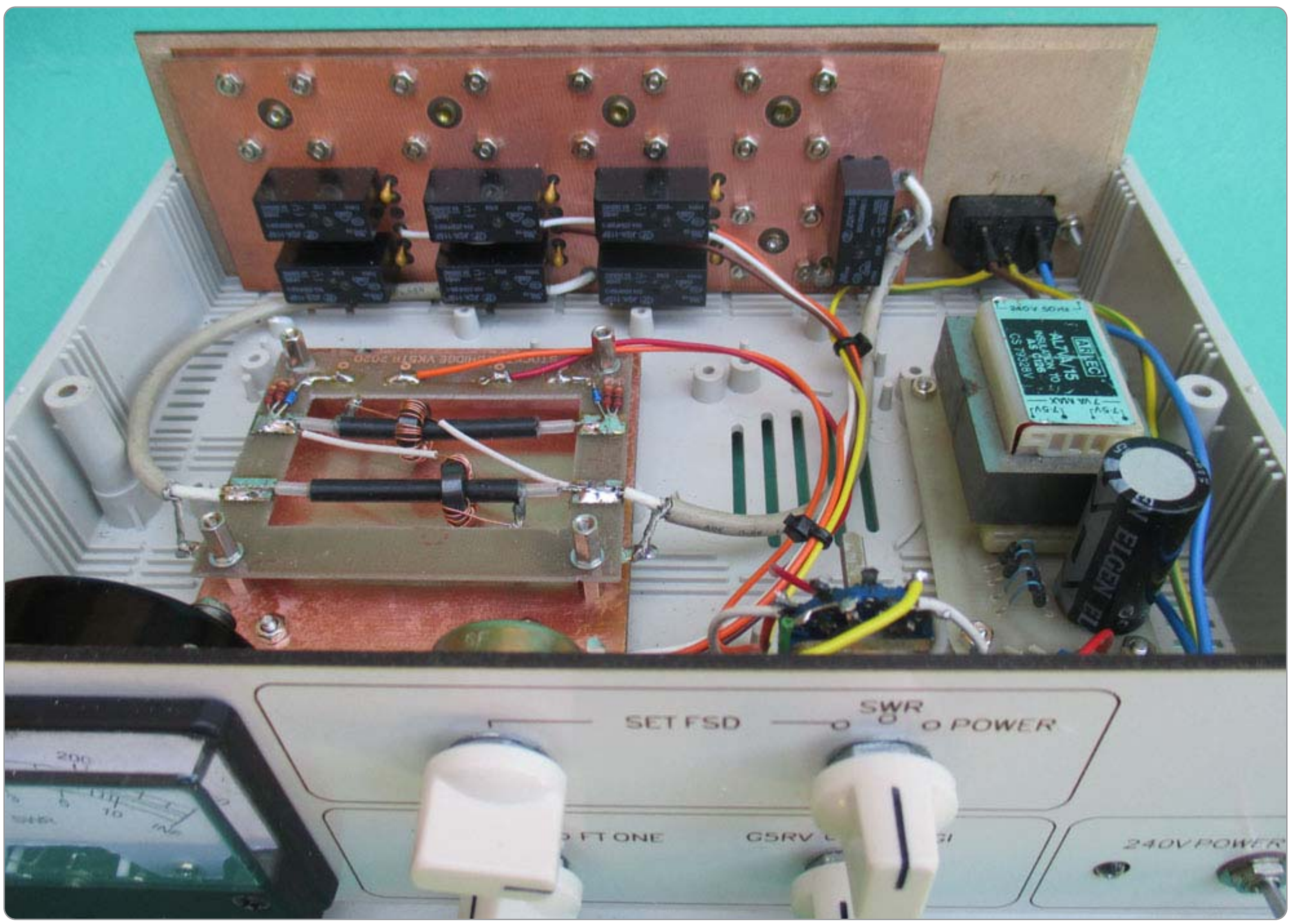


*Photo 3: Internal view of the antenna switcher, showing the relay switching board mounted to the rear panel, the Stockton bridge VSWR and RF power meter section at left, mounted to a 'ground plane' of an un-etched PCB. The VSWR/power sensor circuit comprises two ferrite toroids wound with 22 turns of enameled wire and a 'single turn' primary – a length of coax with the shield grounded at one end (**only**); you can see that each length of coax has the shield grounded at the **opposite** end to the other. The simple power supply is at right. Although I used a PCB, the circuit is so simple it's not necessary.*

Epilogue

So, that's it. Hopefully, you now have enough information to build a switching and metering system for your own well-appointed radio shack and station, with its many transceivers and antennas. Note that the switch described in this article cannot be reversed, i.e. transceivers and antenna connections reversed. There is insufficient isolation for safety between the current antenna connectors.

As a final comment, if readers want a copy of the main printed circuit board, or a print of the meter scale, please email me, at: *endsodds@internode.on.net*.

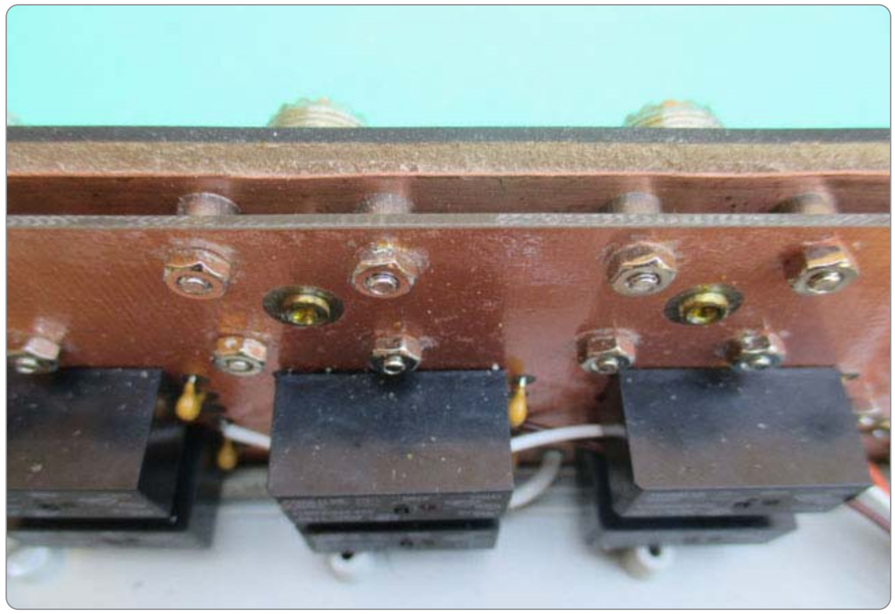


Figure 2: Close-up view of the rear panel, showing the "second ground plane" in the form of a solid metal sheet that is clamped to the inside rear of the panel, behind all the antenna sockets.

WIA news

Are we there yet?

Solar Cycle 25 has begun, says the US's National Oceanic and Atmospheric Administration (NOAA).

The Solar Cycle 25 Prediction Panel, an international group of experts co-sponsored by the National Aeronautics and Space Administration (NASA) and NOAA, has announced that solar minimum occurred in December 2019, marking the start of a new solar cycle.

Because our Sun is so variable, it can take months after the fact to declare this event.

Sunspots are an indicator of solar activity, often as the origins for giant explosions – such as solar flares or coronal mass ejections (CMEs) – which can fart solar material, light, and energy, into space.

"As we emerge from solar minimum and approach Cycle 25's maximum, it is important to remember solar activity never stops; it changes form as the pendulum swings," said Lika Guhathakurta, solar scientist in the Heliophysics Division at NASA Headquarters in Washington.

NASA and NOAA, along with the Federal Emergency Management Agency and other federal agencies and departments, work together on the National Space Weather Strategy and Action Plan to enhance space weather preparedness and protect the nation from space weather hazards.

NOAA provides space weather predictions and data from satellites to monitor space weather in real time.

Space weather predictions are also critical for supporting the US's space program spacecraft and astronauts.

Surveying this space environment is the first step to understanding and mitigating astronaut exposure to space radiation. Scientists are working on predictive models so they can one day forecast space weather much like meteorologists forecast weather on Earth.

To determine the start of a new solar cycle, the prediction panel consulted monthly data on sunspots from the World Data Center for the Sunspot Index and Long-term Solar Observations (SILSO), located at the Royal Observatory of Belgium in Brussels, which tracks sunspots and "pinpoints" the solar cycle's highs and lows. Australia's Space Weather Services is another World Data Centre (www.sws.bom.gov.au).

"We keep a detailed record of the few tiny sunspots that mark the onset and rise of the new cycle," said Frédéric Clette, SILSO's director and one of the prediction panelists. "These are the diminutive heralds of future giant solar fireworks. It is only by tracking the general trend over many months that we can determine the tipping point between two cycles."

With solar minimum behind us, scientists expect the Sun's activity to ramp up toward the next maximum, predicted to be in July 2025.

Doug Biesecker, panel co-chair and solar physicist at NOAA's Space Weather Prediction Center (SWPC) in Boulder, Colorado, said Solar Cycle 25 is anticipated to be as strong as the last solar cycle, which was a below-average cycle, but not without risk (in terms of space weather).

"Just because it's a below-average solar cycle, doesn't mean there is no risk of extreme space weather," Biesecker said. "The Sun's impact on our daily lives is real and is there. SWPC is staffed 24-7, 365 days a year because the Sun is always capable of giving us something to forecast."

NOAA has a new satellite, the Space Weather Follow-On L-1 observatory, which launches in 2024, before Solar Cycle 25's predicted peak. More information on sunspots and the solar cycle is in *AR* magazine, Issue 3, 2020, pp 11-15.