New Probes for Tracing Electrical Noise

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Stations of the DSN are vulnerable to many kinds of noise. To discover and measure potentially harmful noise, three new designs of probes are described. The article also suggests design practices that defend the station against noise.

Electrical noise is any signal-like disturbance capable of obscuring information. The most perfect timing pattern in a station would be noise if it merged into a computer input. Since the receivers, transmitters, and control rooms contain hundreds of signal circuits capable of inadvertent mutual coupling, there is a constant danger of noise interference. Further, the sudden or gradual deterioration of electrical devices and power distribution systems endangers proper operation of the rest of the station. Prevention, measurement, and cure of noise is a paramount concern.

Some noise is distributed on the primary power wires. Once introduced into the power system, the noise may travel throughout the station. Other noise is coupled from rack to rack over defective cables or on cables which are imperfectly coupled to the chassis.

The ideal signal cable would carry a current from source to load without radiating any part of it, and would be able to pass through a noisy environment without picking up any noise. Actual cables generally are very close to the ideal. In the DSIF stations, there are hundreds of signal paths that usually have no evidence of any undesired coupling.

Most of the signals are low impedance, with currents typically tens of milliamperes. These currents travel in circuits, going out from the source on one conductor and returning to the source on a second. Sometimes the return path is poorly defined. This is a serious oversight; the return path requires the same attention as the signal lead. Noise problems nearly always come from separation of the two signal paths.

Whenever the current in a conductor changes, the magnetic field around it also changes. Every signal, therefore, sets up a varying magnetic field around each of the two conductors in which it flows. If the two conductors are very close to each other, the currents flowing in opposite directions almost perfectly cancel each other's magnetic fields. In this case, little power is radiated. But if the two branches of the circuit are separated, they both become radiators.

Not only do these separated paths radiate signals along the way, they at the same time become susceptible to noise from other sources. The converse is also true; a circuit that cannot radiate is immune to pickup.

A properly made coaxial cable, properly used, demonstrates the principle of balancing the signal and its return. The cable has no external field at all, and external fields do not induce signals into the cable. (Some coaxial cables sacrifice a little quality to improve mechanical flexibility or to reduce cost, but even they come close to the ideal.) The coaxial cable must have all of its return signal in the shield. If any of the current escapes to some other path, the cable loses its effectiveness. This can result from poor equipment design that allows alternate paths for part of the signal circuit. It can also come from a termination that has a bad connection to either one lead of the cable or to the mating connector.

In a multiconductor cable it is best to use a separate return lead for each signal circuit. For best isolation the pair of leads should be twisted together. Telephone cables are outstanding in the use of careful twisting of pairs of wires. Crosstalk is usually negligible even with miles of cables containing many circuits.

To measure noise currents in cables and ground buses, three convenient probes have been developed. The first is a modified clip-on ammeter. It can be snapped over any cable up to 2.8 cm in diameter and is useful over a frequency range of 30 Hz to 400 kHz. The second is insensitive to low frequencies, but has high output from about 5 kHz to nearly 1 MHz. The third is useful from 300 kHz to 10 MHz. Each probe is used as a current-to-voltage transducer, usually with an oscilloscope as a readout. Each reads only the unbalanced component in a cable or group of cables, without disconnecting the cable. These probes are sensitive enough to read any potentially harmful currents. They can be used without disturbing any of the equipment. Using an oscilloscope to show the waveform and frequency of signals makes it easy to identify and trace the noise paths.

The first probe, useful for low-frequency currents from 1 milliampere to 100 amperes, is modified from an RS-1 Amprobe ammeter. As supplied by Amprobe, the clip-on ammeter has provision for reading voltage with a pair of leads attachable to the bottom. The lead terminals are used to connect a cable to the oscilloscope, and, inside the instrument, a jumper is added from one terminal to one end of the pickup coil. The other end of the coil already has a lead to the second terminal. Modification steps are as follows:

(1) Remove the instrument rear cover. A special deep socket wrench must be used.

(2) With the back off, add the jumper (5) and resistor (6) as shown in Fig. 1. The 100-ohm ⅛-watt resistor is included as a fuse. (The voltmeter is still good to about 40 volts.)

(3) When replacing the back, it is safer to use the plastic screws to prevent high-voltage shock.

(4) Label the instrument to indicate that it should not be used for reading line voltages. Its usefulness as a normal clip-on ammeter is not affected.

(5) Cut the two connectors from the voltage leads that came with the instrument. Attach them to the center conductor and shield respectively of a coax or shielded cable.

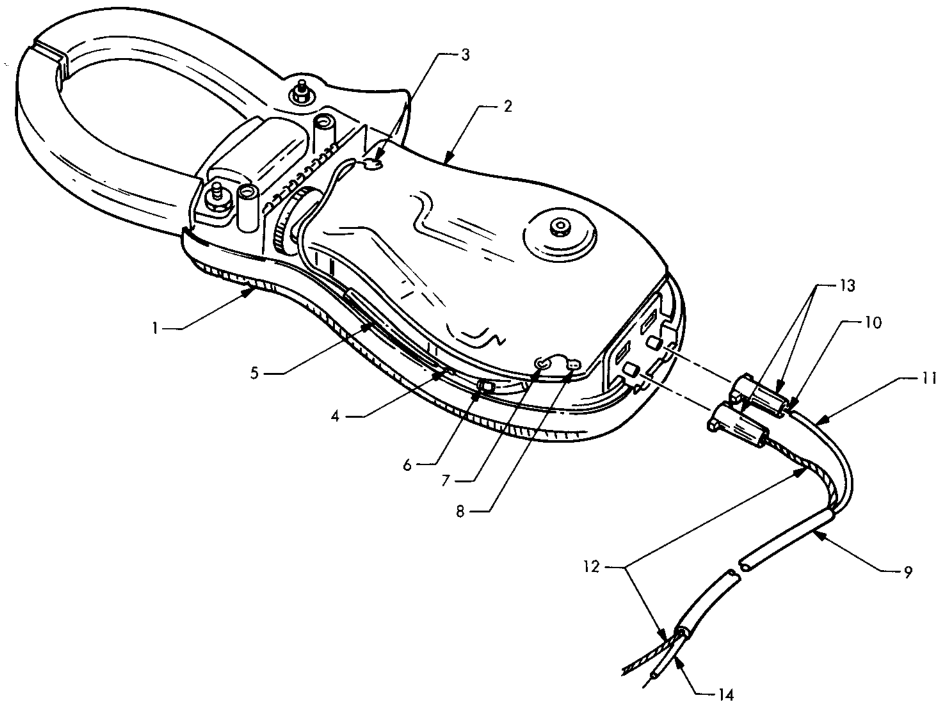
(6) The instrument is now usable, but the frequency response shows a gradual rise to about 700 Hz, and a gradual decline to 10 kHz. A pad has been added on the far end of the cable. This pad adjusts the output to the characteristics shown on Fig. 2. The pad schematic is Fig. 3. The pad has a J. W. Miller 70F223A1 subminiature 2.2-mH choke, a 470-ohm 1-watt resistor, and a 5-μF capacitor in series.

To make a higher frequency probe, use a core of a single piece of nickel alloy foil 2×12 cm. It is insulated and cushioned with a wrap of polyolefin shrink tubing; then 1000 turns of No. 34 AWG wire are bank-wound in one pass around the middle of the core. A 1000-ohm resistor shunts the coil, and a coaxial cable connects it to the oscilloscope. The probe is bent into a U-shape and an outer jacket added. The construction of this probe is described more completely in DSIF-STD-00006 (Ref. 1). Figure 4 shows a typical calibration curve. Several were also made with an outer shield covering the exterior bend of the U. These probes respond only to cables within the curve, not those on the outside. The response curve has somewhat better high-frequency output than Fig. 4 shows. If the central core is made from tinned soft steel, the output is low at frequencies below 10 kHz. If aluminum is used for the core, there is little response below 100 kHz.

To trace leakage signals above 300 kHz, there are excellent pickups available at radio parts stores. The ferrite core antennas used in miniature broadcast receivers have high sensitivity from 0.3 to 10 MHz. Those intended to be tuned by 365-pF capacitors are best. The response should be flattened by a 1000-ohm shunt, and a pair of short leads used to connect to an oscilloscope or RF voltmeter.

Reference

1. *DSIF Standard Grounding System Requirements for Deep Space Stations*, DSIF-STD-00006, June 6, 1972 (JPL internal document).



1. AMPROBE MODEL RS-1
2. PRINTED-CIRCUIT BOARD
3. SOLDER ONE END OF 24 AWG WIRE TO UPPER RIGHT-HAND PAD OF PRINTED-CIRCUIT BOARD
4. SOLDER RESISTOR LEAD TO INSULATED 24 AWG WIRE
5. INSTALL TEFLON SLEEVE
6. INSTALL RESISTOR
7. ROUTE RESISTOR LEAD THROUGH INSULATED EYELET IN PRINTED-CIRCUIT BOARD
8. SOLDER RESISTOR LEAD TO LOWER LEFT-HAND PAD OF PRINTED-CIRCUIT BOARD
9. CUT COAXIAL CABLE RG-180B/U TO 3-m LENGTH
10. CENTER CONDUCTOR
11. INSULATION
12. SHIELD
13. SOLDER CONNECTOR SUPPLIES WITH AMPROBE MODEL RF-1 TO COAXIAL CABLE
14. STRIP AND TIN COAXIAL FOR OUTPUT SIGNAL TO OSCILLOSCOPE

Fig. 1. Field modification of Amprobe Model RS-1

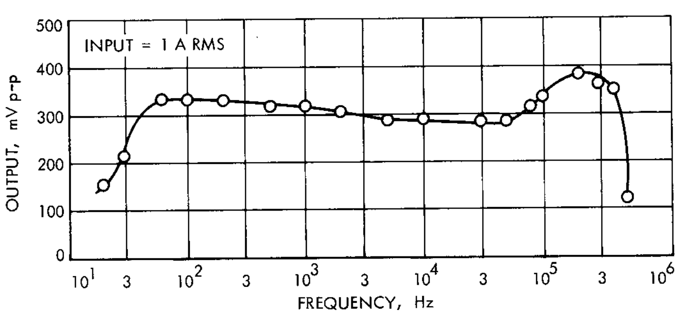


Fig. 2. Calibration curve of low-frequency probe

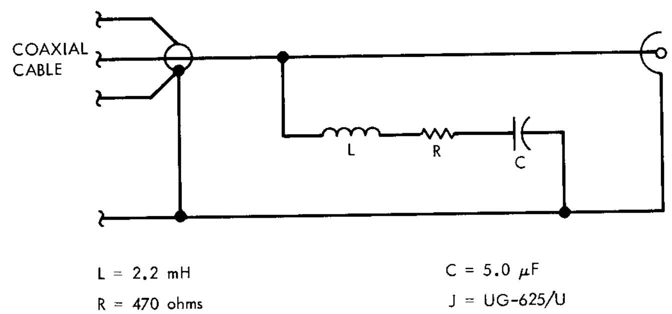


Fig. 3. Pad for low-frequency probe

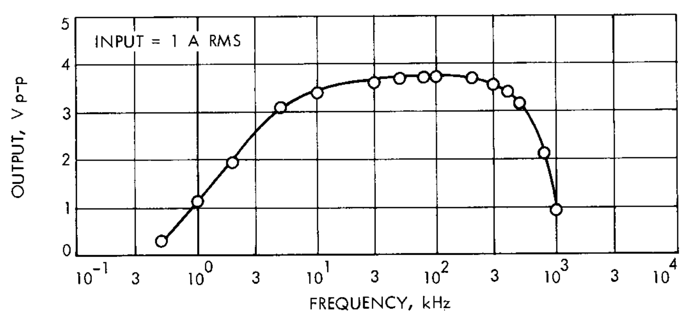


Fig. 4. Calibration curve of high-frequency probe