Wire Line — A New and Easy Method of Microwave Circuit Construction

Simple tools and techniques provide access to the microwave frequencies.

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In our branch of the Communications Satellite Corporation (COMSAT), hams are not plentiful. So when the authors met and found that a common interest in amateur microwave techniques existed, we formed a lunch-time technical society at the plant. After a lot of discussion, research and breadboarding, we came up with a new technique that will certainly put microwave circuit construction within easy reach of any amateur.

"Wire line" is a greatly simplified transmission line construction technique which does not require extreme precision or pc-board etching and uses commonly available parts and tools. By using only a soldering iron, diagonal cutters and a ruler, it is possible to build microwave mixers, oscillators, super-regenerative detectors and other microwave rf circuits with surprisingly good results.

Theory

Transmission line circuits are necessary at microwave frequencies to keep the circuit losses under control, to conduct the signals from one place to another and to match one circuit to the next. One of the more popular microwave transmission-line techniques is called stripline. Stripline employs an etched copper strip transmission line over a ground plane. Literature is available describing stripline techniques and circuit design.[1] Much of this information may be useful in understanding wire line techniques.

The wire-line approach employs single-wire transmission lines using a ground-plane image. Theory indicated that there was no reason this technique would not work at microwave as well as at audio frequencies. The formula

$$Z_o = \frac{138}{\sqrt{e}} \log_{10} \frac{4h}{d}$$

where

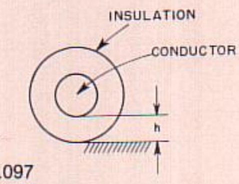
Z_o = line impedance
e = dielectric constant of the medium
h = height above ground
d = diameter of the wire

would closely approximate the final results.

If the wire is insulated and the insulation is brought into contact with the ground plane, a simple, stable and adjustable circuit element is formed. The spacing of the wire above the ground plane is determined by the insulation on the wire. We found that the effective value of the dielectric constant, e, may be

Table 1

Required Wire Spacing for a 51.5-Ohm Impedance Line



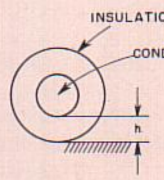
Wire Gauge (AWG)	*Diameter (in.)*	*Dielectric Constant (e)* 1	2	3	4	5
12	0.080	0.007	0.027	0.049	0.072	0.097
14	0.064	0.006	0.022	0.039	0.057	0.077
18	0.040	0.004	0.014	0.024	0.036	0.048
22	0.002	0.002	0.009	0.015	0.022	0.030
30	0.010	0.001	0.003	0.006	0.009	0.012

The required wire-to-ground-plane spacing (h) in inches is shown below the various dielectric constant values. Inches × 25.4 = mm.

Table 2

Spacing Versus Impedance Using No. 14 Wire

Impedance (Z_o) in ohms	*Spacing (h) in inches*
30	0.006
40	0.019
50	0.036
70	0.089
100	0.256
120	0.481



This table gives the required spacing (h) in inches for no. 14 AWG wire with a dielectric constant (e) of 3 to provide a specific impedance. Inches × 25.4 = mm.

[1]Notes appear on page 23.

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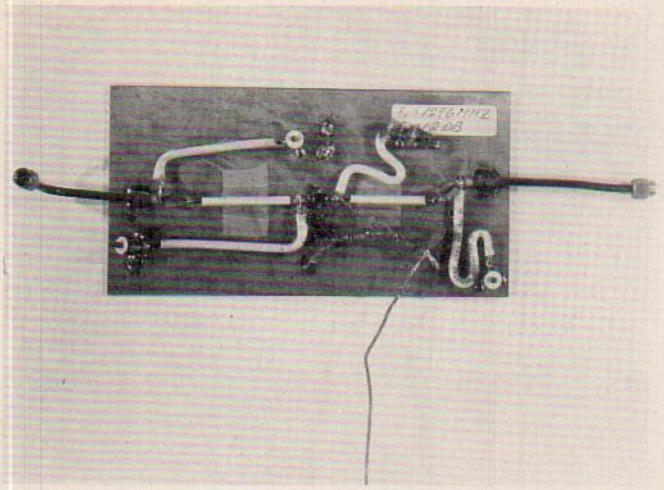

Fig. 1 — A wire line 1296-MHz rf amplifier. The simplicity of construction is quite evident.

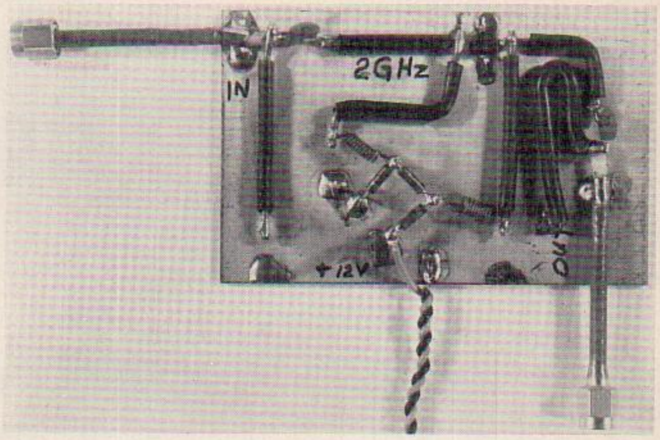

Fig. 3 — Another wire line amplifier, this one constructed for 2 GHz. Note the absence of tuning capacitors; it was tuned by cutting the stubs to proper size.

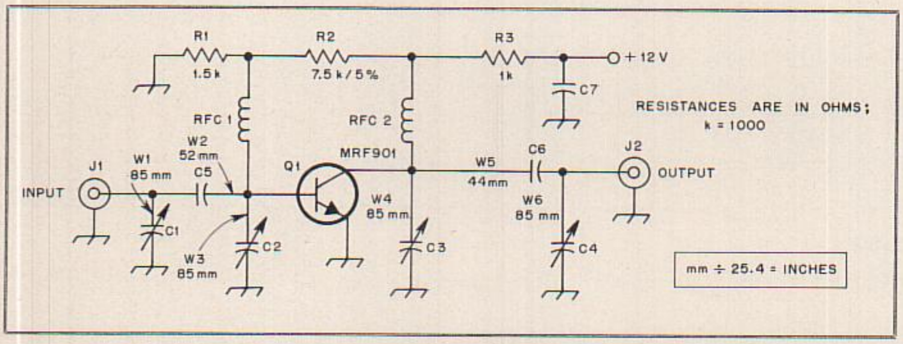

Fig. 2 — Schematic diagram of the 1296-MHz amplifier. If the dimensions shown for W1 through W6 are followed closely, excellent results should be obtained. All resistors are 1/2-watt types.

C1-C4, incl. — 15 pF polypropylene trimmer.
C5, C6 — 47 pF disc ceramic ("zero" lead lengths should be used).
C7 — 0.01 μF disc ceramic.
J1, J2 — SMA connectors.
Q1 — Motorola MRF-901, npn silicon transistor, f_T = 4.5 GHz.
RFC1, RFC2 — 10 turns no. 30 enam., 1/8-inch (3-mm) dia, close wound.

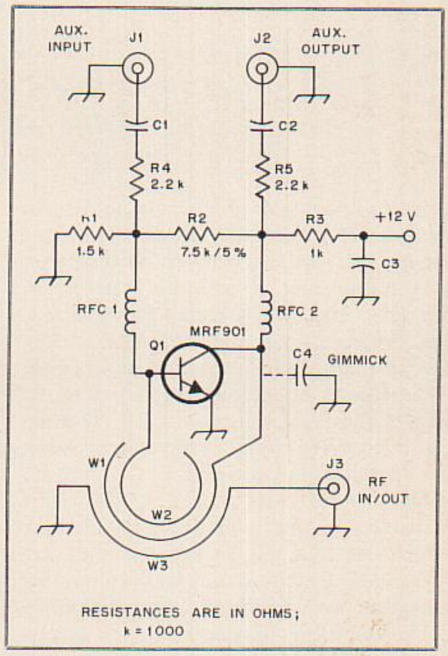

Fig. 4 — The "triple-threat oscillator." Description and arrangement of the lines (W1-W3) and the tuning procedure are discussed in the text. All resistors are 1/2-watt types.

C1-C3, incl. — 0.01 μF, 100 V.
C4 — Gimmick capacitor made from an 8-32 screw threaded into the pc board near W1.
J1-J3, incl. — SMA connectors.
RFC 1 — 10 turns no. 30 enam., 1/8-inch (3.2 mm) dia.
RFC2 — 10 turns no. 30 enam., 1/4-inch (6.4 mm) dia.
W1 — 1.85 inches (47 mm) no. 14 wire (see text).
W2 — 1.46 inches (37 mm) no. 14 wire (see text).
W3 — See text.

adjusted to take into account the amount of the field both in the air and in the insulation.

Experimental results indicated that a piece of no. 14 AWG, PVC-insulated house wire glued to a copper ground plane has an impedance of 58 ohms. This produces an effective dielectric constant of about 2 for PVC in this configuration. Table 1 shows the general range of results that may be expected using common wire sizes with varying types of insulation. Table 2 indicates that a maximum impedance in the range of 100-120 ohms is expected because of spacing and radiation problems; at the low end, 30 ohms could be considered a limit.

One item of interest is the double-stub tuner, a short section of transmission line about 3/8 wavelength long with an adjustable stub tuning line attached at either end. This produces a matching system much the same as a pi-network tuner, but one that will operate in the microwave range. Using small ceramic,[2] glass or polypropylene tuning capacitors on the ends of the stub lines (each about 3/8 wavelength long) will allow a wide range of impedance matching. If a different impedance-matching range is necessary, the lines may be shortened or lengthened easily. Using this method, it is possible to "screwdriver adjust" most microwave circuits for best results.

An RF Amplifier and Oscillator

Amplifiers that have been designed and built using wire line have surpassed initially expected results and have often exceeded the specification sheet gain for the transistor used. The amplifier shown in Figs. 1 and 2 was built using ordinary house wire, polypropylene variable capacitors and an ion-implanted Motorola MRF-901 transistor. This unit works very well at 1296 MHz and, if the dimensions given are duplicated, similar results should be obtained. Other amplifiers (such as the 2-GHz unit shown in Fig. 3) have been built for use at frequencies up to 3 GHz. The total cost of such a project is about $5.50.

The "triple-threat" oscillator shown in Fig. 4 will function as an ordinary oscillator, as a crystal injection-locked oscillator and as a super-regenerative detector. In order to build a receiver, one must have a local oscillator and its output should be clean.[3] Bipolar devices often produce parametric parasitic frequencies and noise, and our first conventionally developed circuits were no exception.