LM- and BC-221 Frequency Multiplier

Generate detectable signals up to 1000 MHz.

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Hams have the advantage and privilege of being able to design, build, test, and operate equipment in the ham bands; these privileges come with the passing of the ham license examination. The ham license is a "license to learn," and provides the incentive to get involved with electronic equipment and circuits. A large abundance of equipment has been developed over the years since the 1930s, with a large portion of it built for World War II. Out of that equipment inventory, and of specific interest to hams, are the LM- and BC-221 frequency meters.

These measurement instruments have been superseded by counters and phase-locked loop signal generators, but the usefulness of the old frequency meter still abounds. LM- and BC-221 frequency meters are showing up at swap meets for dirt cheap prices, making them readily available for the experimenter and his applications. The LM- and BC-221 are really precision measuring instruments that had an original frequency measurement accuracy of 0.01%—some may still be that good today. Without attention over the years their accuracy may have degraded some, but the usefulness of the instruments has not. These instruments retain their short-term stability and also have a long-term stability exceeding that of most of the currently available self-excited signal sources. My point is that each of these instruments should be given a second chance as a viable piece of test equipment.

Ham ingenuity is required to find new uses and applications for desirable equipment. One such application for old frequency meters is to use them as stable frequency sources capable of generating signals up to at least 450 MHz, with some detectable signal up to 1000 MHz. The fundamental tuning ranges for these two instruments are typically 125–250 kHz and 2–4 MHz in two bands. In its original condition, the frequency meter provided suitable harmonics up to at least 20 MHz from the 2–4 MHz band. To utilize the 2–4 MHz range for use in the VHF and UHF region, it is necessary to build a frequency multiplier capable of providing some usable energy at harmonic multiples up to at least 250 times (333 times for 1000 MHz) the fundamental frequency.

There are many designs and techniques available for frequency multiplication applications; the duty of the experimenter is to find a better solution to the problem to meet his requirements. As the saying goes, "the design is never finished until the last experimenter is dead," and that's true for the frequency multiplier circuit presented here. Electronic circuits are presentations of ideas for project solutions, and for this project as well as others, experimenters are encouraged to use, modify, and change the circuit as deemed necessary to meet their application needs.

The circuit

The objective of the frequency multiplier circuit is to increase both the signal amplitude and the harmonic content of the output signal such that the signal can be detected well up into the UHF range. Some of the available frequency multiplier circuit designs and other solutions are elaborate and complex, and may use parts not readily available to the experimenter. Therefore, a simple and repeatable design was sought, one which used older available parts that would be easy to assemble.

That objective was met and is shown in **Fig. 1,** where the parts are an

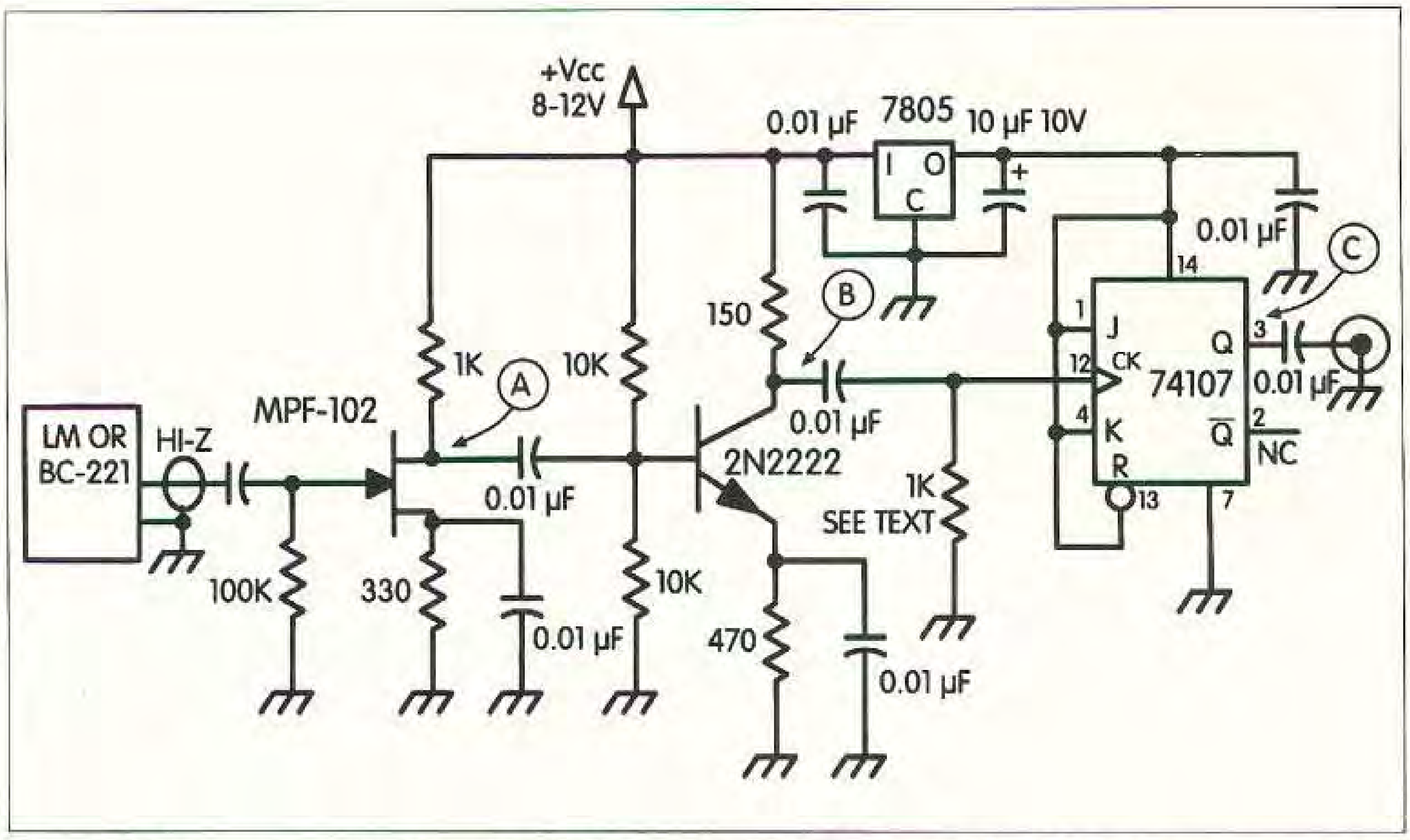

Fig. 1. Frequency multiplier circuit that extends the LM- or BC-221 frequency output up into the UHF range.

MPF102 JFET, 2N2222 transistor, 74107 J-K flip-flop, and 7805 (LM340-5) voltage regulator. A CMOS 4027 was tried as an alternate for the 74107, but it failed to toggle for whatever reason. The purpose of trying the 4027 was to take advantage of the higher VCC voltage tolerance. Also, selecting the 74107 part required the use of the five-volt regulator. Should a 74107 part not be available, the following parts may be considered for substitution: 7473, 74LS78, 74276, 74376, and 74F112 (the 54XX series should also work satisfactorily in this application). In any case, only one section of the chip is used for the multiplier. The remaining input pins must be grounded while the outputs are allowed to float.

An FET is used as an input stage to accommodate the high output impedance of the frequency meter. Because of the high impedance, a flexible shielded cable, such as coax, should be used to reduce extraneous signal pickup. Any length less than about four feet is suggested in order to keep down the capacitive load on the frequency meter's output circuit. Attachment to the meter is accomplished by drilling a small hole in the case near the RF terminal for a small self-tapping screw, which is used for holding a solder lug as shown in **Fig. 2**. The FET and transistor stages provide sufficient signal amplitude, though marginal, to toggle the clock input of the 74107. The resistor connected from the 74107 pin 12 to ground deserves special attention. It is necessary to select a value for this resistor which allows the clock signal to swing sufficiently above and below the "maybe" region, because the resistor establishes the DC reference level for the chip input. A 1 k resistor satisfied the requirement for the prototype circuit but may need to be adjusted slightly to accommodate a different 74107 or one of its substitutes.

Circuit waveforms

Fig. 3 shows the signal waveforms obtained at three points within the circuit; it may be used as a guide in building the frequency multiplier. Waveform A is nearly a sine wave at the drain terminal of the MPF102. The 2N2222 reshapes the waveform to a near pulse as shown in B. As expected

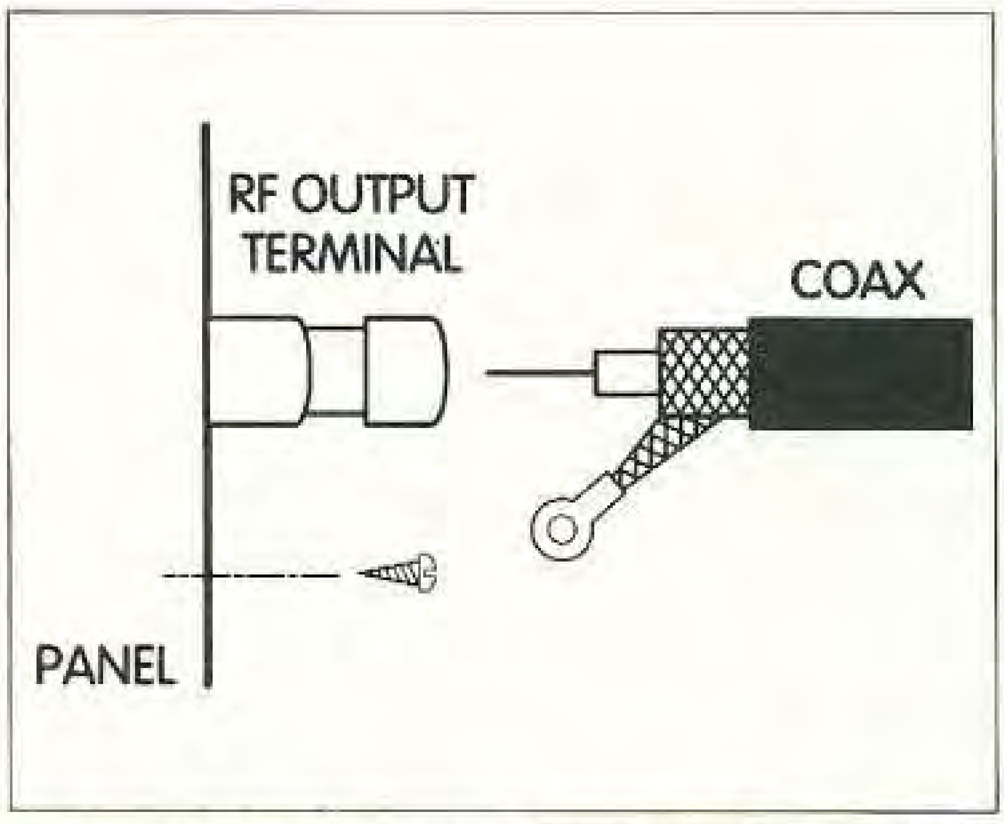

Fig. 2. Coax attachment. Small hole drilled for self-tapping screw which is used to ground the coax shield.

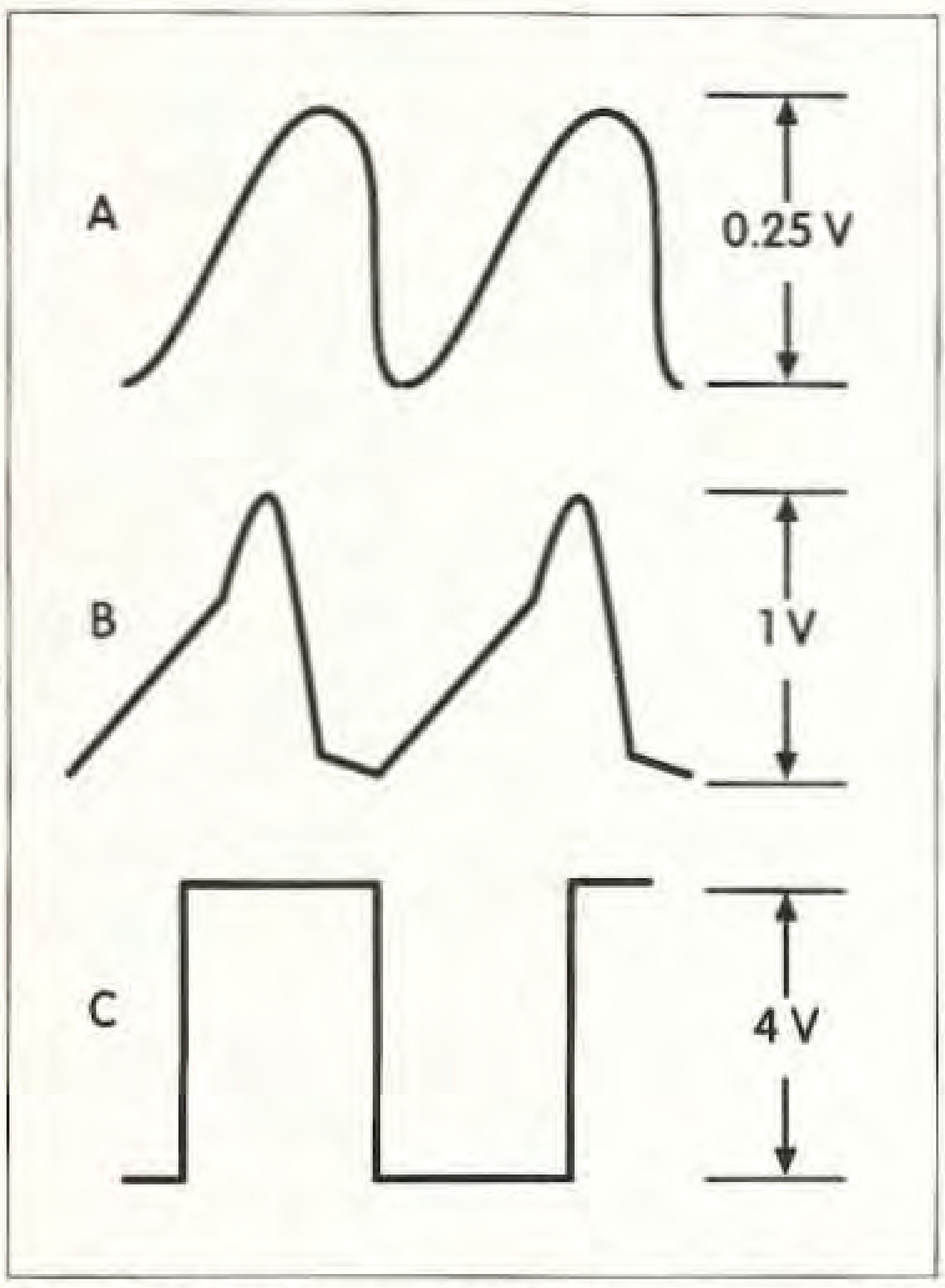

*Fig. 3. Waveforms obtained at points A, B, and C as indicated in **Fig. 1**. Voltage values are approximate.*

and desired, the waveform at C is nearly a square wave. A pure square wave would contain only odd harmonic energy of the fundamental. But sufficient distortion is present in the output of the 74107 to provide energy at both odd and even harmonics of the fundamental.

To understand the signal output characteristics, signal levels at various frequencies were measured. A curve was drawn between the points, as shown in **Fig. 4**, to show a general amplitude profile. The measurements were made using a 3 MHz signal from the frequency meter and the amplitude was measured at the indicated frequencies. At 450 MHz (150th harmonic), the signal was detected at a level of 0.1 µV. At 300 MHz, the signal rose to 0.3 mV. Judging from the test data, the frequency meter and multiplier combination is usable as a signal source up into the 450 MHz band (although marginal above 450). A signal was detected as high as 1000 MHz (333rd harmonic), but the amplitude may be useful depending upon the sensitivity of the receiver. No attempt was made to determine if a signal could be detected above 1000 MHz, but it is reasoned that some detectable signal is likely. The length of the coax between the multiplier and receiver greatly affected the detectable signal level, with short cable lengths being preferred. For measurement results shown in **Fig. 4**, the coax was six feet of RG-58.

While monitoring at 450 MHz, the source frequency was manually swept from 2 to 4 MHz to determine which frequency might produce the highest amplitude. I found that frequencies in the range of 3.4 to 3.8 MHz produced a higher amplitude, approaching 10 µV. The amplitude variance shown in the curve is a function of the distortion in

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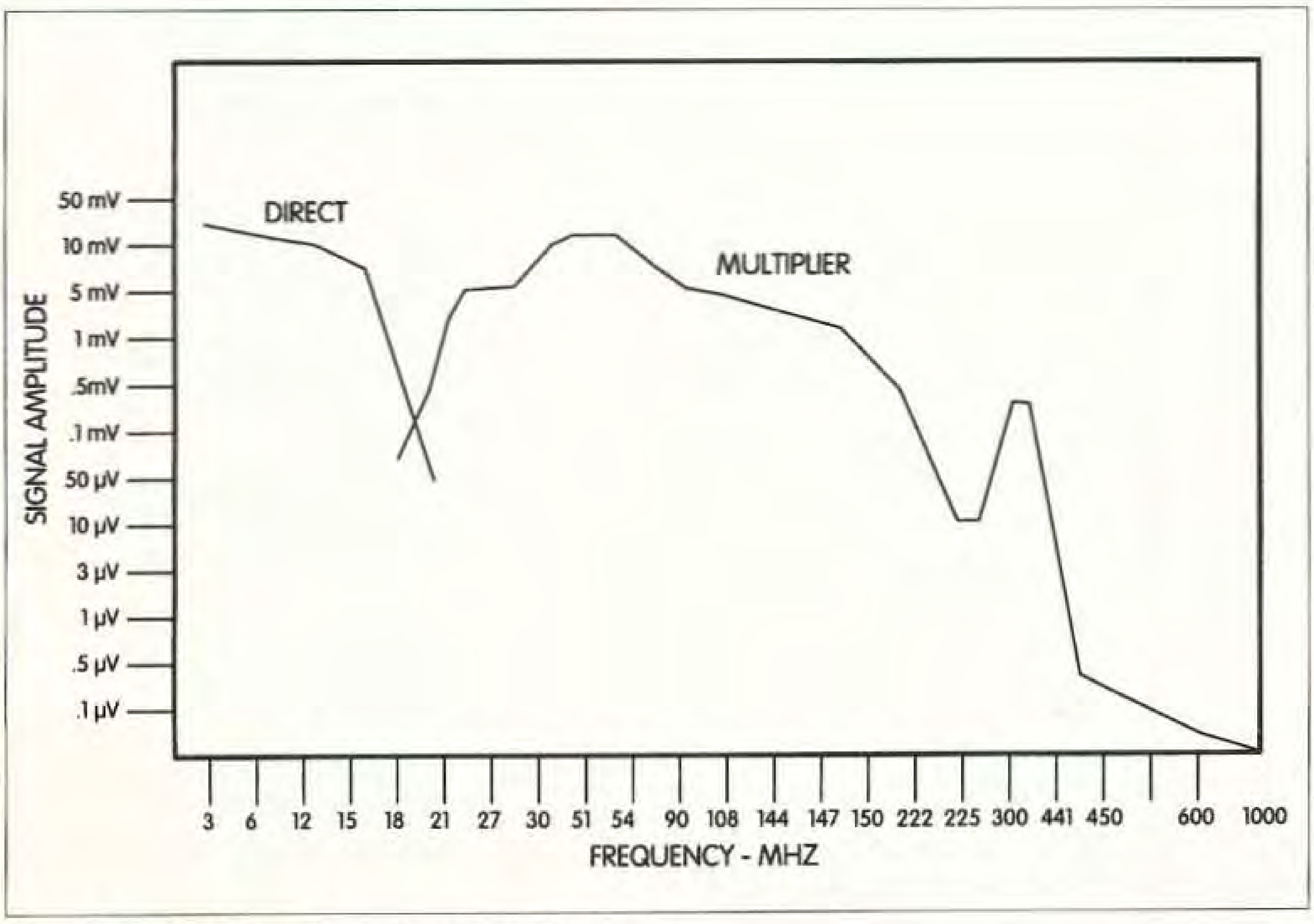

Fig. 4. Typical signal amplitude vs. frequency.

LM- and BC-221 Frequency Multiplier

continued from page 19

the 74107's output waveform as well as the harmonic number.

Different chips might exhibit a different set of energy levels at the indicated harmonic, but the general profile would be expected to remain. Should a spectrum analyzer be used to view the output of the multiplier, it would display a comb of signals, each separated by the frequency of the source. The amplitude of the comb display would follow the curves shown in **Fig. 4**.

No attempt was made to include a resonator at the desired output frequency. However, the addition of a resonator would improve the amplitude of the signal present at the frequency of resonance. Conceivably, the use of a resonator following the multiplier might create usable signals in the 900–1296 MHz bands. An experiment to prove the validity of the scheme is warranted. A suitable resonator could be made using a stripline, cavity, or coil and capacitor. The higher-Q stripline and cavity are recommended to better the chances of success.

Construction

Construction of the multiplier circuit is simple and noncritical. Common parts were selected for the project; they may be mounted using any desirable method—from the "dead bug" style to a printed circuit board.

The resistors used in the project may be from 1/8 to 1/2 W, but the board layout I used (not shown; you can easily make your own) accommodated 1/4 W ones. All of the coupling and bypass capacitors, except C8, were 0.01 µf disc ceramics. But any value from 0.005 µF to 0.1 µF is satisfactory and may be used in any combination of availability.

Conclusion

The LM- and BC-221 frequency meters were built as quality and precision measuring instruments. That quality has probably been retained over the years. I suggest that you salvage these instruments from their resting places on dusty shelves and the chopping blocks at swap meets.

Build the frequency multiplier circuit and bring your instrument back to life as an accurate and stable signal source capable of generating signals as high up as 1000 MHz. As indicated by this experimental project, everything is simple and non-complex, yet the project achieves reasonable results in terms of frequency multiplication.

Don't be afraid to change and/or modify the circuit in any way you like. The fun of a project is to experiment with different values, parts, and concepts to achieve a useful result. 73

Parts List

R1	100 k 1/4 W resistor Jameco #29997
R2, R8	1 k 1/4 W resistor Jameco #29663
R3	330 1/4 W resistor Jameco #30867
R4, R5	10 k 1/4 W resistor Jameco #29911
R6	470 1/4 W resistor Jameco #31165
R7	150 1/4 W resistor Jameco #30162
C1, C2, C3, C4, C5, C6, C7, C9	0.01 µF disc cap 50–100 V Jameco #15229, Hosfelt #15-888
C8	10 µF 16 V radial cap Jameco #94211, Hosfelt #15-853
Q1	MPF102 JFET transistor Jameco #26403, NTE213
Q2	2N2222 NPN transistor Jameco #28628, #38236 NTE123A
U1	LM340-5 5 V regulator Jameco #51262, Hosfelt #7805
U2	74107 JK flip-flop Jameco #49234, Hosfelt #74LS107

***Table 1.** Parts list.*