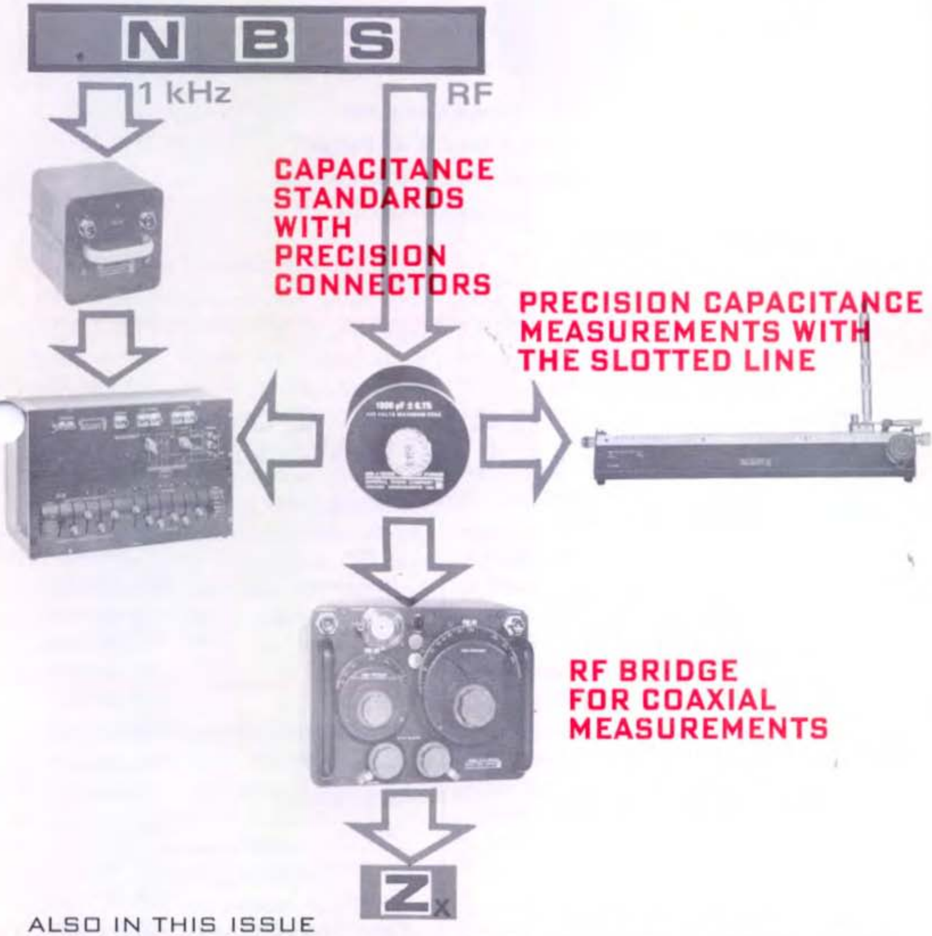
THE GENERAL RADIO

Experimenter



ALSO IN THIS ISSUE

PROGRAM PRESET UNIT FOR FREQUENCY SYNTHESIZERS

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CAPACITANCE STANDARDS WITH PRECISION CONNECTORS

One of the chief problems in the calibration of two-terminal capacitance standards has been the variation in stray capacitance from one binding-post connection to another. Significant improvement in this area had to await the development of a coaxial connector with high repeatability, low inductance, and a precisely known reference plane. Fortunately, such connectors are now available, and they are put to good use on the new Type 1406 Capacitance Standards.

The precision coaxial connector has made its reputation on its low SWR in the gigahertz region, and few if any microwave standards laboratories are now without benefit of these connectors. The well justified attention to uhf characteristics has tended to obscure the fact that the precision coaxial connector is also a powerful tool at radio frequencies and all the way down to dc.[1]

The introduction of the Type 1406 Coaxial Capacitance Standards, equipped with GR900® precision coaxial connectors, focuses attention on the usefulness of such connectors at low frequencies. The 1406, available in five values from 50 to 1000 pF, would be a good standard capacitor even with ordinary connectors. With the highly repeatable, low-inductance GR900, it offers performance never before commercially available at radio frequencies.

The significance of the precision connector on the standard capacitor is far-reaching. The National Bureau of Standards will no longer calibrate capacitors with binding posts or other unshielded terminals[2]; the Bureau further states[3] that maximum calibration accuracy can be offered only when the capacitor is equipped with precision coaxial connectors meeting the IEEE Standard.[4]

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[1] R. N. Jones and L. E. Huntley, "Precision Coaxial Connectors in Lumped Parameter Immittance Measurement," *Proceedings of the IEEE*, Vol 55 No. 6, June 1967.

[2] Federal Register, Vol 32, No. 15, 24 January, 1967.

[3] R. N. Jones and R. L. Jesch, *High Frequency Immittance Calibration Services of the National Bureau of Standards*, U. S. Department of Commerce, National Bureau of Standards, October 1, 1965.

[4] D. E. Fossum "Progress Report of the IEEE Instrumentation and Measurement Group Technical Subcommittee on Precision Coaxial Connectors," *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-13 No. 4, December 1964.

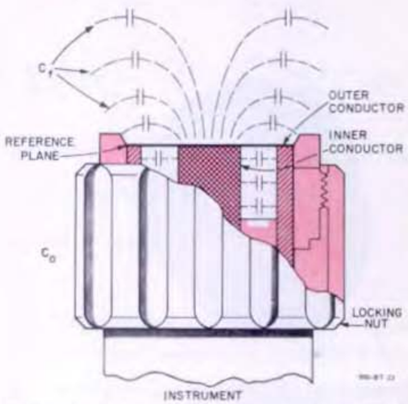

Figure 1. Open GR900® precision coaxial connector showing fringing capacitance (C_f).

The emphasis of NBS and of others on coaxial connection is easy to understand. Two-terminal capacitance standards are usually calibrated in terms of the capacitance added to the bridge terminals. When these terminals are binding posts, this added capacitance is not clearly defined, since the addition of the standard changes the stray capacitance between the binding posts and also adds capacitance from the capacitor case to the high binding posts.[5] Different bridge and binding-post configurations mean different strays and consequent variations in the net capacitance added to different instruments by the same standard.

The use of a GR900 precision connector for the terminals changes all this. The connector has a precisely known reference plane, and capacitance can be defined and measured as the internal capacitance up to this reference plane.

An open GR900 connector on an instrument has a fringing capacitance (Figure 1) consisting of the total stray capacitance beyond the reference plane.

[5] John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, July 1959.

When a capacitor with a GR900 connector is added to the open connector, the fringing capacitance is eliminated, and the net increase in capacitance equals the value of the capacitor as measured at its reference plane minus the value of its fringing capacitance. The fringing capacitance of a GR900 connector is 0.155 ± 0.008 pF in the usual environment on a bridge, with no conductors within several inches of the open connector. Even better accuracy can be obtained if an initial balance is made with a small capacitor whose value is known precisely at its reference plane.

The low over-all inductance of the new standard means that the capacitance change with frequency is negligible up into the megahertz range (see Figure 2). The difference between the 1-kHz and the 1-MHz values of capacitance is, for the lower capacitance values, smaller than the uncertainty of the 1-kHz measurement on a precision bridge. Assuming that the useful upper-frequency limit is the point where the effective capacitance differs from its 1-kHz value by 10 percent, the 1000-pF capacitor is useful to 16 MHz, the 50-pF unit to 83 MHz.

Because of its wide frequency range and its acceptability by the National Bureau of Standards for calibration above 30 kHz, the 1406 capacitor is expected to be used chiefly as a standard for the calibration of two-terminal bridges and other impedance-measuring instruments. Of course, the most convenient arrangement and the most accurate measurements result when the bridge is equipped with a GR900 connector, as is the rf bridge described elsewhere in this issue. The next best thing is a precision adaptor, and two

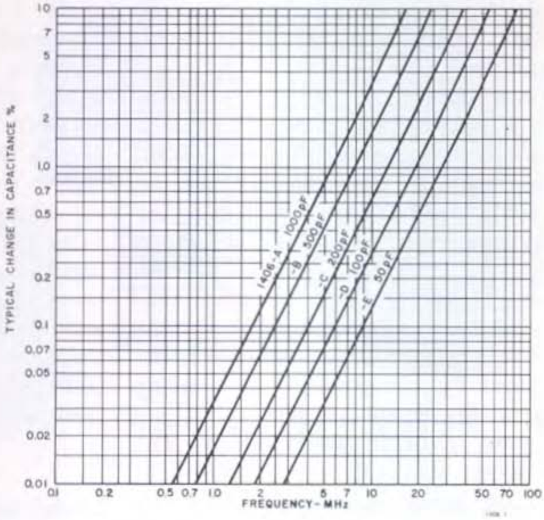

Figure 2. Typical percent increase in capacitance of Type 1406 Coaxial Capacitance Standards with frequency.

Figure 3. Type 1615-P2 Coaxial Adaptor.

of these have been designed specifically for use with bridges. One, the Type 1615-P2 (Figure 3), is used with the 0.01%, 1-kHz Type 1615-A Capacitance Bridge. A trimmer capacitor is included so that the terminal capacitance can be effectively eliminated from the measurement.

The Type 900-Q9 Adaptor (Figure 4) mates with binding posts on ¾-inch spacing, such as are used on the GR 716 Capacitance Bridges, with other posts with a ¼-28 thread, or with tapped holes, on ¾-to-1-inch spacing. Among the many instruments accommodated are the Boonton Radio Type 260A Q Meter and the Boonton Electronics Model 75 Capacitance Bridge.

Figure 4. Type 900-Q9 Adaptor.

Description

The air capacitor in the Type 1406 Standard is a rigid assembly of parallel plates mounted in a shielded cylindrical enclosure, with a GR900 precision connector providing the terminals. Metal parts are aluminum to minimize stresses caused by differences in thermal expansion. The capacitor plate assembly is insulated from the mounting plate by cross-linked thermoset polystyrene insulators, treated to reduce the effects of humidity. The heavy cover plate is threaded to screw into the cylindrical housing; the resulting rigid assembly eliminates mechanical instabilities that could cause small variations in capacitance.

Calibration

A calibration certificate supplied with each capacitor gives the measured value of capacitance at 1 kHz, the temperature and relative humidity at the time of measurement, and the calculated effective capacitance of the unit at 1 MHz. The 1-kHz capacitance applies at the well defined reference plane of the GR900 connector, and it is obtained by comparison with working standards whose absolute values are known to within ±0.01 percent. The working standards are in turn calibrated periodically against NBS-calibrated reference standards.

The 1-MHz value of capacitance is calculated from the measured low-frequency capacitance and the known inductance of the capacitor. Of considerable importance is the fact that, due to the low inductance and the rugged construction of the standard, any change in its 1-MHz capacitance value will be accompanied by a proportional change in its 1-kHz capacitance value. Thus a standard can, for example, be NBS-calibrated at 1 MHz, and this high-frequency value can thereafter be monitored by means of periodic 1-kHz measurements.

— R. W. Orr

A brief biography of Mr. Orr appeared in the August 1966 *Experimenter*.

SPECIFICATIONS

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kHz and at a specified temperature and relative humidity. The measured capacitance is the capacitance at the reference plane of the GR900 connector. This value is obtained by comparison, to a precision better than ±0.01%, with working standards whose absolute values are known to an accuracy typically ±0.01%, determined and maintained in terms of reference standards periodically calibrated by the National Bureau of Standards.

Stability: The capacitance change is less than 0.05%/year.

Accuracy: Capacitance is adjusted to within 0.1% of nominal value.

Residual Parameters: See table below. Dissipation factor is given for 40% RH and varies as the 3/2 power of frequency above about 100 kHz.

Insulation Resistance: Greater than 10^{12} Ω at 23°C and less than 50% RH.

Temperature Coefficient of Capacitance: Typically 10 to 20 ppm/°C between 20 and 70°C.

Accessories Available: Type 1615-P2 for convenience in calibrating with 1615-A Capacitance Bridge; Type 900-Q9 Adaptor for connection to GR 716 Capacitance Bridge, Boonton Q Meter, and other binding-post-equipped instruments.

Terminal: GR900 precision coaxial connector.

Mounting: Aluminum panel and cylindrical case.

Dimensions: 3 by 5¼ in. (77 by 135 mm).

Weight: Net, 1¾ lb (0.8 kg); **shipping** (est) 5 lb (2.3 kg).

Catalog Number	*Type*	*Nominal Capacitance*	*Peak Volts*	*Typical Dissipation Factor* 1 kHz (40% RH)	*Typical Dissipation Factor* 1 MHz	*Typical Inductance*	*Price in USA*
1406-9701	**1406-A**	1000 pF	700	3×10^{-6}	50×10^{-6}	8.6 nH	**$120.00**
1406-9702	**1406-B**	500 pF	900	5×10^{-6}	30×10^{-6}	8.4 nH	**115.00**
1406-9703	**1406-C**	200 pF	1200	20×10^{-6}	25×10^{-6}	8.1 nH	**110.00**
1406-9704	**1406-D**	100 pF	1500	30×10^{-6}	20×10^{-6}	7.6 nH	**105.00**
1406-9705	**1406-E**	50 pF	1500	50×10^{-6}	15×10^{-6}	6.7 nH	**100.00**
1615-9602	**1615-P2 Coaxial Adaptor**, GR900 to binding post						**60.00**
0900-9874	**900-Q9 Coaxial Adaptor**, GR900 to binding post						**50.00**

COAXIAL-CONNECTION CAPABILITY ADDED TO RF BRIDGE

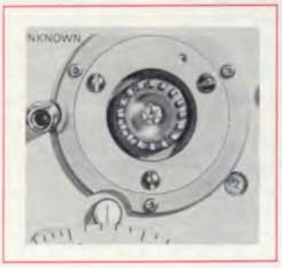

Figure 1. Type 1606-B RF Bridge. Inset shows GR900® adaptor in place.

The new Type 1606-B RF Bridge (Figure 1) differs from its predecessor by the simple but important fact that its "unknown" terminals can be quickly and easily converted to accept a GR900® precision coaxial connector. This means that the bridge can be precision-calibrated against GR900 components or against the Type 1406 Coaxial Capacitance Standards described elsewhere in this issue. It also means that components and networks equipped with GR900 connectors can be accurately measured on the bridge. Moreover, almost any type of coaxial connector can be connected to the bridge terminals through one of the many GR900 adaptors available.

To review the principal characteristics of the 1606 RF Bridge: Resistance and reactance are indicated directly in ohms, over a frequency range from 400 kHz to 60 MHz. Measurements are made by a series-substitution method, in which the bridge is first balanced with its unknown terminals short-circuited, then balanced with the unknown impedance connected. Since its introduction, the bridge has been very widely used in rf measurements on antennas, transmission lines, networks, and components.

Conversion for Coaxial Connection

The Type 1606-P2 Precision Coaxial Adaptor Kit (Figure 2) converts the Type 1606-B RF Bridge either to the standard GR900 configuration or to a 14-mm flange connection. In addition to the necessary GR900 and flange connector hardware, the kit includes both GR900 and GR874 50-ohm compensating lines, for matching out the bridge terminal capacitance.

With the GR900 adaptor in place, the bridge can be quickly converted for use with any of the popular coaxial connectors, via GR900 precision adaptors. With the GR874 50-ohm compensating line in place, the extensive line of GR874 adaptors is added to the compatibility list. The many connection possibilities are given in Table 1.

The most precise measurements can be performed with the direct GR900 connection. In this case the unknown is

Figure 2. Type 1606-P2 Precision Coaxial Adaptor Kit.

assembled with a GR900 connector for the direct measurement on the bridge.

Precise Bridge Calibration

Perhaps the most important advantage of the precision coaxial connector is that it serves as the essential link between the bridge and the most accurate available calibration standards, including new coaxial capacitance standards (see page 3) acceptable for calibration by the National Bureau of Standards.

With the coaxial connection, a precision calibration is a quick and easy matter. The bridge is balanced with the GR900 adaptor (from the 1606-P2 kit) in place and with the standard connected to it. Then, if the bridge is to be used without the GR900 adaptor, the known capacitance of the adaptor is subtracted out. In addition, the 1606-P2 kit contains a spacer sleeve that can be added to duplicate the GR900 adaptor capacitance in open-terminal measurements (e.g., measurements where non-coaxial components are connected directly to the bridge).

An alternative practice is to leave the GR900 adaptor in place and to add to it a 900-Q9 adaptor, which converts from GR900 to binding posts. The parasitic inductance and capacitance values are furnished with this adaptor.

Some of the many standards that can be used to calibrate the bridge are listed in Table 2.

— J. Zorzy

A brief biography of Mr. Zorzy appeared in the August 1966 *Experimenter*.

TABLE I

Adaptors from 1606-B Bridge (with 1606-P2 Kit) to Various Coaxial Systems

Connector on Unknown	*Through GR900**	*Through GR874***
APC-7 (7mm)	900-QAP7	874-QAP7L
BNC JACK	900-QBP	874-QBPA
BNC PLUG	900-QBJ	874-QBJL
BRM JACK	900-QMMP	874-QMMPL
BRM PLUG	900-QMMJ	874-QMMJL
C JACK	900-QCP	874-QCP
C PLUG	900-QCJ	874-QCJL
Dezifix	900-QPF7	
GR874	874-Q900L	
HN JACK		874-QHPA
HN PLUG		874-QHJA
LC JACK		874-QLPA
LC PLUG		874-QLJA
LT JACK		874-QLTP
LT PLUG		874-QLTJ
Microdot JACK		874-QMDP
Microdot PLUG		874-QMDJL
OSM† JACK	900-QMMP	874-QMMPL
OSM† PLUG	900-QMMJ	874-QMMJL
Precifix A	900-QPF7	
SC JACK	900-QSCP	874-QSCP
SC PLUG	900-QSCJ	874-QSCJL
TNC JACK	900-QTNP	874-QTNP
TNC PLUG	900-QTNJ	874-QTNJL
UHF JACK		874-QUP
UHF PLUG		874-QUJL

* For 50-ohm compensation, add 1606-3060 unit, supplied with 1606-P2 kit.
** For 50-ohm compensation, add 1606-3070 unit, supplied with 1606-P2 kit. Otherwise, add 874-Q900L adaptor.
† Registered trademark of Omni Spectra, Inc.

TABLE 2

GR900-Equipped Standards

Capacitance		900-LZ6 Reference Air Line	4.0000 pF
1406-A Coaxial Capacitance Standard	1000 pF	900-LZ7H Reference Air Line	5.0000 pF
1406-B Coaxial Capacitance Standard	500 pF	900-LZ10 Reference Air Line	6.6667 pF
1406-C Coaxial Capacitance Standard	200 pF	900-LZ15 Reference Air Line	10.000 pF
1406-D Coaxial Capacitance Standard	100 pF	900-LZ30 Reference Air Line	20.000 pF
1406-E Coaxial Capacitance Standard	50 pF	900-WO4 Open-Circuit Termination	2.67 pF
900-L10 Precision Air Line	6.6 pF	*Resistance*	
900-L15 Precision Air Line	10 pF	900-W50 Standard Termination	50 Ω
900-L30 Precision Air Line	20 pF	900-W100 Standard Termination	100 Ω
900-LZ5 Reference Air Line	3.3333 pF	900-W200 Standard Termination	200 Ω
		900-WR110 Standard Mismatch	45.45 Ω
		900-WR120 Standard Mismatch	41.67 Ω
		900-WR150 Standard Mismatch	33.33 Ω

SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 400 kHz to 60 MHz. Satisfactory but somewhat less accurate operation can be obtained at frequencies as low as 100 kHz and somewhat above 60 MHz.

Reactance: ±5000 Ω at 1 MHz. This range varies inversely as the frequency; at other frequencies the dial reading must be divided by the frequency in MHz.

Resistance: 0 to 1000 Ω.

ACCURACY

Reactance: At frequencies up to 50 MHz, $\pm 2\% \pm (1 + 0.0008\,Rf)\,\Omega$ where R is the measured resistance in ohms and f is the frequency in MHz.

Resistance: At frequencies up to 50 MHz,

$$\pm \left[1\% + 0.0024 f^2 \left(1 + \frac{R}{1000}\right)\% \pm \frac{10^{-4}\,X}{f}\,\Omega + 0.1\Omega\right]$$

(where X is the measured reactance in ohms). Subject to correction for residual parameters.

GENERAL

Generator: External only (not supplied) to cover desired frequency range. Recommended, Type 1211-C and Type 1215-C Unit Oscillators, Type 1330-A Bridge Oscillator, Type 1310-A Oscillator, Type 1003 Standard-Signal Generator.

Detector: External only (not supplied). A heterodyne detector, Type DNT-6, is recommended for use above 3 MHz. A well shielded radio receiver is also satisfactory.

Accessories Supplied: 2 leads of different lengths to connect unknown impedance to bridge terminals; ½-in. spacer and ¾-in. screw to mount component to be measured directly on bridge terminals; 874-R22LA Patch Cord.

Accessories Available: Luggage-type carrying case, 1606-P2 Precision Coaxial Adaptor Kit.

Mounting: Welded aluminum cabinet.

Dimensions (width × height × depth): 12½ × 9½ × 10¼ in. (320 × 245 × 260 mm).

Weight: Net, 23 lb (10.5 kg), with case, 29 lb (13.5 kg); **shipping,** 30 lb (14 kg), with case, 31 lb (14.5 kg).

Specifications for 1606-P2

Capacitance Added: By adaptor to GR900, 0.38 pF at reference plane (less fringing capacitance); by flange adaptor, 0.18 pF.

Weight: Net, 10 oz (270 g); **shipping,** 12 oz (340 g).

Catalog Number	*Description*	*Price in USA*
1606-9702	**1606-B R-F Bridge**	**$1050.00**
1606-9601	**1606-P1 Luggage-Type Carrying Case**	**25.00**
1606-9602	**1606-P2 Precision Coaxial Adaptor Kit**	**95.00**

PRECISION CAPACITANCE MEASUREMENTS WITH A SLOTTED LINE

The precision slotted line, normally considered a microwave instrument, can be used to measure the capacitance of any high-Q capacitor from about one-third its self-resonant frequency to nearly the self-resonant frequency. Such measurements are made at General Radio in connection with the calibration of new coaxial capacitance standards (see page 3). From the basic capacitance measurements, the self-resonant frequency is determined by extrapolation, and the parasitic inductance of the capacitor is easily calculated. Since the departure from the "dc" capacitance reaches 12.5 percent at one-third the resonant frequency, the slotted-line measurement covers a very important frequency range.

Principle of Measurement

This unusual application of the slotted line results from the fact that, for a small capacitive reactance, the minimum position of the slotted-line probe is relatively close to the unknown terminals, in terms of wavelength. In lumped-parameter terms, the inductance of the coaxial slotted section is generally great enough to resonate the capacitor being measured. The slotted-line probe, in the active sense, behaves like an adjustable short-circuiting wiper whose position along the line corresponds to the minimum of the voltage standing-wave pattern. The slotted line thus acts as a precision variable inductor.

At higher frequencies, usually above 50 MHz, this lumped representation is no longer accurate, and distributed transmission-line formulas must be used for capacitance determination.

Procedure

The use of a GR900® precision coaxial connector is highly recommended for maximum accuracy and is essential if the measurement is to be made on a Type 900-LB Precision Slotted Line. The Type 1406 Coaxial Capacitance Standards are equipped with GR900 connectors and can thus be directly connected to the precision slotted line for high-frequency calibration. For capacitors not so equipped, the Type 900-Q9 Adaptor (see page 5) offers a convenient binding-post connection.

The measured values are slotted-line minimum position and exact frequency. The capacitance is calculated

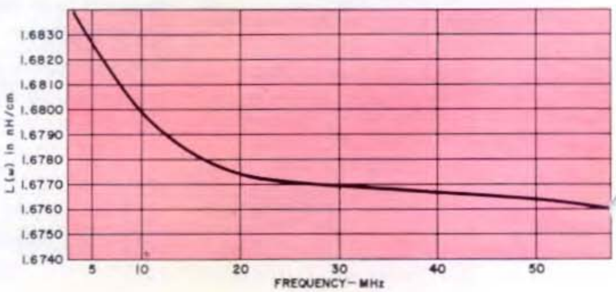

Figure 1. Typical inductance per unit length for Type 900-LB Precision Slotted Line.

from: $$C_x = \frac{1}{\omega^2 L(\omega)\ell}$$

where ω = angular frequency ($2\pi f$)
$L(\omega)$ = slotted-line inductance per unit length
ℓ = physical length from unknown reference plane to slotted-line minimum.

The inductance per unit length of the slotted line is not easily calculable because the conductors are usually made of one material and plated with another. Skin-effect calculations are not reliable because the plating thickness is not known accurately enough. This inductance has been measured for a number of TYPE 900-LB Precision Slotted Lines; the results are shown in Figure 1, which may be used to determine $L(\omega)$. These measurements were made by means of a solid-silver TYPE 900-LZ Reference Air Line, whose characteristics are determined on an absolute basis from its dimensions and known values of conductivity. The dimensions are known to within about ±0.01%; conductivity is known to within about 10%. A high degree of accuracy for conductivity is not required in this calibration; the skin-effect correction is, for example, less than 1% above 1 MHz, and the resulting error in the skin-effect correction would be only about 0.05% in this case.

The physical length from the unknown reference plane to the slotted-line minimum position can, with care, be measured to an accuracy of about 0.05 percent. A final measurement accuracy of about 0.3 percent is possible, taking into account the variation of $L(\omega)$ from one slotted line to another.

The residual inductance of the capacitor can be determined from the measured data, if a low-frequency capacitance measurement is performed. The TYPE 1615-A Capacitance Bridge can be used to measure capacitance (C_o) at 1 kHz to ±0.01 percent. Then the inductance (L_o) required to resonate C_o at the high measurement frequency is determined from

$$L_o = \frac{1}{\omega^2 C_o}.$$

The inductance that actually resonated the capacitor at the high frequency ($L\ell$) is then subtracted from L_o to give the residual inductance of the capacitor.

— J. ZORZY
M. J. MCKEE

"We do not wish to belabor the point, but do want to make a convincing case for using precision connectors wherever accurate and precise immittance measurements are required. . . . The spectacular increase in accuracy of lumped immittance measurements in the past few years has resulted almost entirely from improved standards, instruments, and techniques made possible by precision connectors. This accuracy cannot be realized by the ultimate user of the measurement unless he is willing to accept the small added cost of using precision connectors."

—L. E. Huntley and R. N. Jones, "Lumped Parameter Impedance Measurements," *Proceedings of the IEEE*, Vol 55 No. 6, June 1967.

Figure 1. Type 1163 synthesizer under control of 40-channel program unit. Additional frequencies are available in second 40-channel unit.

A MECHANICAL MEMORY FOR FREQUENCY SYNTHESIZERS

The modern decade-frequency synthesizer can generate precision frequencies defined by many significant figures. This invaluable capability is, unfortunately, accompanied by a minor drawback — the figures must be chosen and set, digit by digit, each time a new frequency is needed.

Whether the frequency is controlled by a series of in-line dials, for good readout, or by a less readable matrix of pushbuttons, manipulation of a series of six or seven or more controls for each desired frequency is a chore, and a mistake in setting is an ever-present danger.

If the synthesizer can be programmed remotely, much of this burden can be transferred to a computer, simple or complex according to the needs of the intended measurements. Less elaborately, when a number of precision frequencies are needed repetitively, storing each of them in a bank of mechanical switches, for instant recall on demand, seems a simple solution to a complex problem. For programmable General Radio synthesizers, this operation is conveniently handled by the new Preset Frequency Program Unit.

The Program Unit has two major parts: an "active housing," cabled to the synthesizer to be controlled, and a "program tray," in which desired frequencies can be set in a convenient array of linear digit switches. A program tray plugged into the housing automatically takes control of the synthesizer. The operator can quickly recover manual control of any or all digits at any time merely by moving the related synthesizer digit dials out of the R (remote) position.

Trays are available with 20 and 40 channels. Of course, any number of trays can be programmed and ready for use when needed. Any tray plugs into the housing in seconds and goes to work instantly.

Figure 1 shows a TYPE 1163 Synthesizer controlled by a program unit. Figure 2 shows the interior of a 40-channel tray, as it appears when it is withdrawn from the housing. In this tray, a matrix of 280 10-position slide-switches is arranged in seven columns and 40 rows. Each row controls a frequency channel. To program a channel frequency, one sets the seven switches in the row to the desired digits by sliding the switch contactors to numbered (0–9) positions on a fiducial strip. A seven-digit frequency can thus be "read into memory" in seconds. Since the trays plug in and out with no permanent wiring connected, a tray can be withdrawn, carried to any convenient location for setting up a program, and restored to use with a minimum of bother.

The two rectangular handles (occupying most of the front of each tray) serve a double purpose: they provide enough leverage to engage or to disengage the multiterminal connectors between tray and housing, and they also carry (under a protective transparent cover) removable cards on which the frequency program set in the tray can be typed or written for instant reference from the front.

In use, any preset channel frequency is selected instantly by the grounding of the appropriate channel line, through a single contact or a transistor switch. Since arrangements for making such

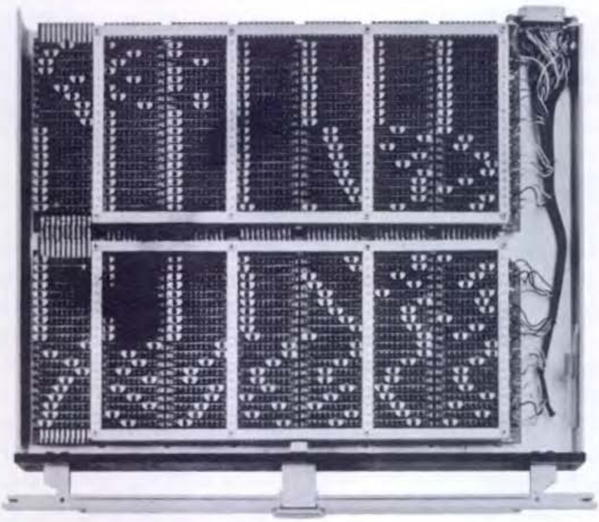

Figure 2. Interior of 40-channel program unit.

Figure 3. Three experimental program-unit switching assemblies.

contact closures will undoubtedly vary widely depending on user requirements, no standard device for performing this function is presently offered. In the system of Figure 1, a 40-pushbutton switching device controls the selection of any of the 40 channels.

Figure 3 illustrates other pushbuttons and switching devices that have been constructed experimentally. These are not offered as standard products, but control units similar to these can be designed and supplied on special order.

Each digit insertion unit is connected to the Program Unit by a 12-wire cable carrying control and supply lines. These cables are available separately, so one need order only as many of them as there are digits to be programmed.

Applications

The Preset Frequency Program Unit will find application whenever two or more different precision frequencies are expected to be used repetitively, as in production alignment and testing of frequency-selective apparatus such as comb-filters, radio receivers, or transmitters. Physicists engaged in nuclear or atomic resonance research should also find this device very useful.

Ephemeris-predictable Doppler shifts could be handled quite simply, by the use of this equipment, in telemetry or communications systems.

Time-sharing of synthesizers, with suitable programming of output switching, will probably offer important economic advantages in many systems.

Two synthesizers can be simultaneously programmed to different groups of frequencies by two trays controlled by a single set of contact closures. Thus, for instance, simultaneous dual outputs with constant frequency separation can readily be achieved. Such setups are useful in heterodyne measuring systems.

External selection apparatus can, of course, be arranged to step through a series of frequencies in a definite sequence at a controlled rate or, alternatively (as by pushbuttons), to provide random access to any frequency stored. The trays can thus become part of highly automated systems, or they can be used more simply to aid manual testing or research.

Conclusion

The frequency program unit is simple in concept and easy to use; applications are expected to be extremely varied, conceived and executed by engineers and other scientists working in the many fields in which frequency synthesizers are so rapidly becoming indispensable.

— A. Noyes, Jr.

A brief biography of Dr. Noyes appeared in the January 1967 *Experimenter*.

SPECIFICATIONS

Capacity: Stores 20 or 40 preset 7-digit frequencies (depending upon model).

Frequency-Selection Input: Mechanical or solid-state switch closure to ground required for each channel. Each closure must be capable of carrying 70 mA with < 0.5-V drop.

Frequency-Selection Output: Circuit closure on 10-line connection to each controlled digit.

Switching Time: <2 ms, depends only on speed of programmable modules.

Accessory Supplied: Connector assembly (two 24-pin connectors) for connection of external selector switches to 1160-P1.

Accessories Required: Cables from 1160-P1 to synthesizer, one per controlled digit: 2-foot length is standard; select to suit RDI modules to be controlled.

Accessories Available: One empty instrument cabinet, convenient in interchanging trays in systems using more than one tray.

Mounting: Relay-rack cabinet.

Dimensions (width × height × depth): 19 × 1¾ × 15 in. (485 × 45 × 385 mm).

Weight: 20 channel, net 9 lb (4.1 kg), shipping 20 lb (9.5 kg); 40 channel, net 11 lb (5 kg), shipping 22 lb (10 kg).

Catalog Number	*Description*	*Price in USA*
	1160-P1 Preset Frequency Program Unit	
1160-9620	20 channels	$1000.05
1160-9640	40 channels	1825.00
1160-9701	**Cable** (2-ft) to any programmable module (1160-RDI-1) up to 100 kHz/step	75.00
1160-9702	**Cable** (2-ft) to 1 MHz/step programmable module (1164-RDI-2) in 1164 models	75.00
1160-9704	**Cable** (2-ft) to 1 MHz/step programmable module (1163-RDI-4) in 1163 models	75.00
1160-9500	**Cabinet**, empty, to store 1160-P1 tray	50.00

GR Product Notes

MORE PROGRAMMABLE PLUG-INS FOR SYNTHESIZERS

Two new remotely controllable digit-insertion units extend the advantages of programmability to all digit stations of all GR 1160-series frequency synthesizers, with the single exception of the top digit of the TYPE 1164.

The 1163-RDI-4 is a plug-in replacement for the DI-4 (× 1 MHz) unit in a TYPE 1163 synthesizer. This means that the entire 12-MHz range of the 1163 is now programmable.

The TYPE 1164-RDI-2 is a programmable plug-in for the × 1 MHz station of an 1164 synthesizer.

These two new programmable modules, like the lower-frequency RDI-1 units, are directly interchangeable with their nonprogrammable counterparts, and converting any station for programmability is just a few seconds' work.

Catalog Number	*Description*	*Price in USA*
	Programmable Digit-Insertion Units	
1163-9479	1163-RDI-4, 1 MHz/step, in 1163 models	$575.00
1164-9479	1164-RDI-2, 1 MHz/step, in 1164 models	555.00
1160-9650	**Hook-Up Cable** for all RDI's, 50 ft, 12 conductor, shielded	15.00

the GR Experimenter

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS 01781

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SEMINAR ON LOW-FREQUENCY STANDARDS

A seminar on Low-Frequency Electrical Standards will be conducted by the National Bureau of Standards at the Bureau's new site at Gaithersburg, Md., from December 11 to 13, 1967.

The seminar will present information on the accurate measurement of electrical quantities and on the calibration of electrical standards. It will cover the measurement methods used by the Bureau to establish and to maintain the basic electrical units and to calibrate customers' standards of resistance, inductance, capacitance, voltage, current, and power from dc through 30 kHz. Emphasis will be on measurement techniques of interest to those working in standards and calibration laboratories.

Those wishing further information should write to R. F. Dziuba, B-162, Metrology Building, National Bureau of Standards, Washington, D. C. 20234.

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