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UNBALANCED CURRENTS IN TWO TERMINAL-PAIR COAXIAL CAPACITANCE BRIDGES

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Abstract: It is necessary to maintain conditions of zero net currents in the cables of ac coaxial bridges. Current equalizers are used for dealing with this problem. It is shown here how they were applied in the construction of a two terminal-pair capacitance bridge with accuracy of about one part in 10^8.

Keywords: current equalizers, unbalanced currents, coaxial bridges.

1. INTRODUCTION

The two terminal-pair coaxial ratio bridge built recently at Inmetro operates mainly at 1 kHz and 1,592 kHz and compares decadic capacitors in the range from 10 pF to 1 nF at the ratios 1:1, 10:1, and 1:10, with an uncertainty of about one part in 10^8. The cable arrangement for the 10:1 ratio bridge is shown in Fig. 1, where C_X is the capacitor under calibration and C_N is the reference standard. The bridge operating principle is discussed in [1].

The capacitance bridge uses a two terminal-pair coaxial design [2]. One way of looking at a coaxial bridge is to see it as two superposed networks. The first of these consists of straightforward meshes of components and the interconnecting wires between them. The second network comprises the shields of the components and the outer, coaxial shield of the connecting cables. The configurations of the two networks are identical and by providing every independent mesh with an equalizing device, the current in the outer shield is constrained to be equal in magnitude and shifted 180° to the current in the components and central conductors. The current in any cable as a whole is zero and no external magnetic field is created. The second network of shields and cable outer conductors has a low impedance, and it is all at nearly the same potential, so that there is no significant external electric field. This construction has the further advantage that such networks do not respond to fields from external sources. Otherwise, the bridge balance conditions could be affected.

Passive current equalization is achieved by threading a coaxial cable through a high permeability (typically Supermalloy) toroidal core so that core and cable act as a 1:–1 transformer. Such equalizers are shown in Fig. 1 as black rectangles (for clarity, we preferred not to draw the coaxial cable shields). Usually, the impedance of the outer conductor is several orders of magnitude smaller than the impedance of the inner conductor (which includes impedance standards, transformers, etc.). A current equalizer has therefore no direct effect on the current flowing along the outer conductor; it just gives rise to an equal current flowing along the outer conductor which is supplied from the same source as the inner conductor.

The principles for finding the proper arrangement of current equalizers in coaxial bridges to achieve equal return currents in the whole bridge network are described in the sequel. The ground network of the bridge (Fig. 2) should be analyzed: (a) evaluate the number of nodes n, branches b and components c of the graph representing the bridge, (b) ensure that the network contains all nodes, that is, $c = 1$, (c) evaluate the number of independent meshes $m = b - n + c$. This is the number of current equalisers required. Every independent mesh of the bridge network must be provided with one current equalizer.

A condition needs to be fulfilled: every node should be connected to the central ground point with just one path without a current equalizer. This central point is connected to earth ground. This condition suggests a procedure to fix the arrangement of the equalizers: start with those branches where the presence of an equalizer is to be preferably avoided, that is, the branches which are directly attached to C_X and C_N (an equalizer will be required at the loop around the capacitors) and the branches attached to the main detector node. Everything connected here will decrease the effective input impedance of the detector (preamplifier) and therefore affect the signal-to-noise ratio. This is particularly important for the measurement of large impedances. After having chosen those branches without equalizers – they are not allowed to form meshes! – branches will have to be added to the nodes not yet connected, again without forming meshes. In this way one arrives at a complete tree linking all nodes without meshes. This tree contain n–1 branches. The remaining m branches then must be equipped with current equalizers.

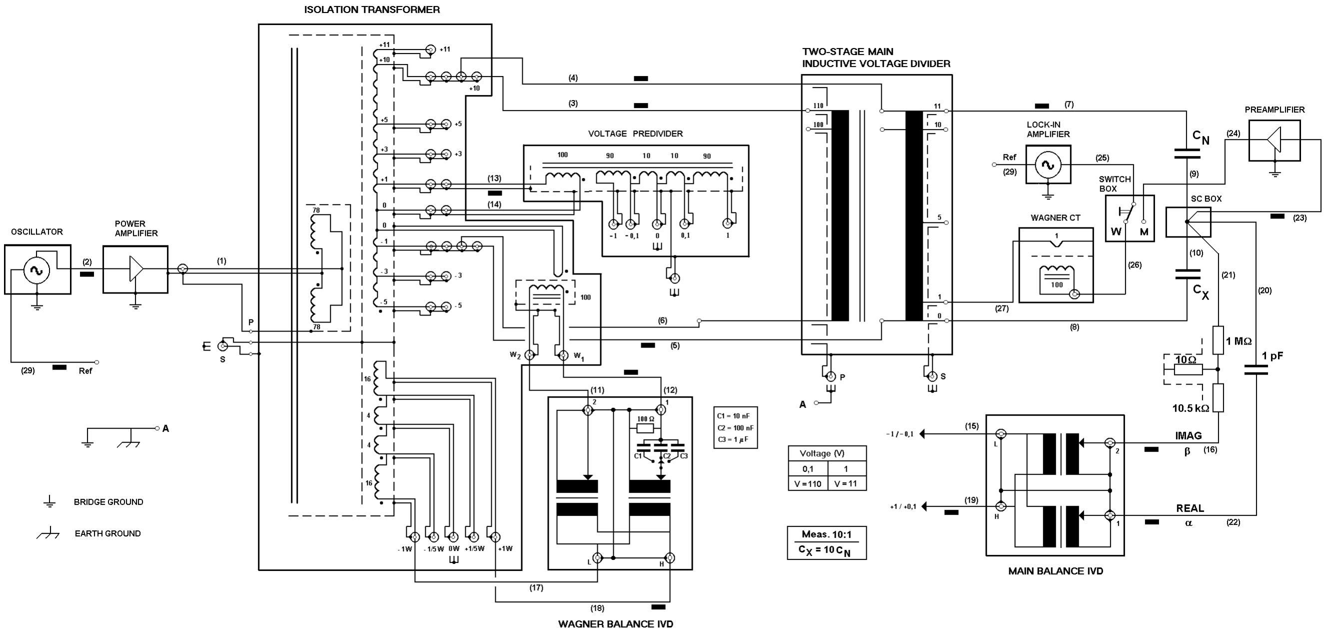

Fig. 1. Detailed scheme of the coaxial capacitance bridge.

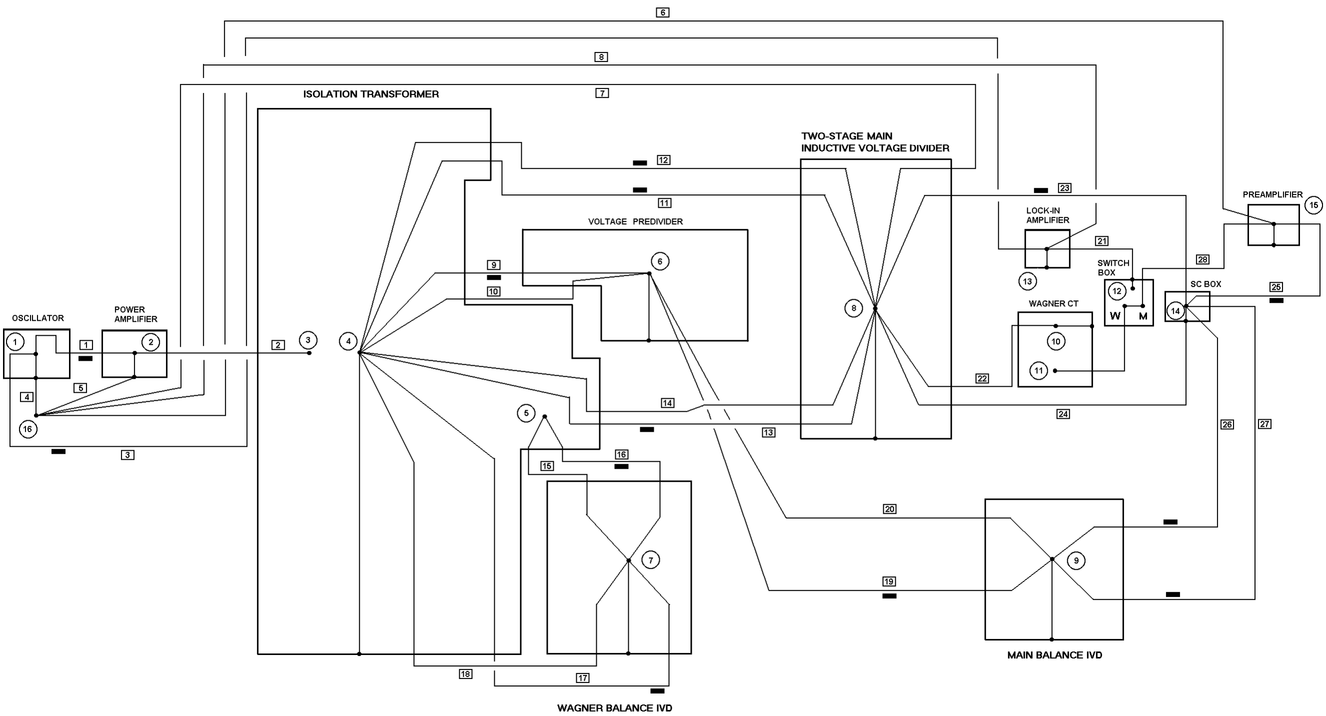

Fig. 2. Ground scheme of the capacitance bridge.

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