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Comparison Table – Matching Unit Designs

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Introduction

The document that follows presents, in table format, a comparison of important characteristics of several of the most common, and best developed, circuit designs for impedance-matching units for use with transmission lines and antennas. These units are also commonly called "antenna tuners."

The table is a companion to two other articles that appear on the CD-ROM that accompanies the *Antenna Book*. The companion articles are entitled "Factors to be Considered in Creating or Assessing Matching-Unit Designs for the MF/HF Spectrum" and "Baluns in Matching Units."

The table is organized into 15 sections, each relating to a particular type of circuit. It is important to recognize that the circuits may be grouped also into two broader categories: network-based designs and inductively-coupled designs. Historically, inductively-coupled designs were predominant. Today, the majority of designs are of the network variety. Only designs 9, 10, 11, and 15 in the table are of the inductively-coupled type. The others are network designs.

Readers steeped in network theory will realize that circuit topologies other than those presented in the table are possible. The table does not seek to exhaust the full range of conceivable topologies but, rather, to address all or nearly all of those that are in regular use among radio amateurs.

The table sections are:

1. L network – low pass (series L, shunt C)
2. L network – high pass (series C, shunt L)
3. Balanced L network – low pass
4. Pi network – low pass (series L, shunt C)
5. T network – high pass (series C, shunt L)

6. Differential T network – high pass (series C, shunt L)

7. Balanced T network – high pass

8. Balanced T network – low pass

9. Inductively coupled – with capacitive voltage divider output (variation ***without*** variable C in series with the primary winding)

10. Inductively coupled – with capacitive voltage divider output (variation ***with*** variable C in series with the primary winding)

11. Inductively coupled – with tapped-inductor output (variation ***with*** variable C in series with the primary winding)

12. "ARRL" tuner (N6BV design) (variation on T network – high pass)

13. "SPC" tuner (W1FB design) (variation on T network – high pass)

14. "Ultimate Transmatch" (W1ICP design) (variation on T network – high pass)

15. "Z Match" (variation on inductively coupled design ***with*** variable C in series with the primary winding)

In each section, the table presents information as to the advantages and disadvantages (and other considerations) of the particular type of circuit. In instances where it was considered especially important for purposes of understanding a design, quantitative information about circuit values is included. Each section also lists commercial examples of the type of circuit, and provides references notes. The notes refer the reader to books and articles where clarification and additional information may be found. In particular, the notes contain information about the formulas and equations that appear in the table, or that were used to calculate the circuit values stated in the table.

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – low pass (series L, shunt C)	for a given frequency and load, only one combination of settings will produce a match; such settings will also coincide with maximum efficiency of power transfer; as a result, the need for metering of transmission-line current or voltage is obviated, and proper tuner adjustment can be achieved with an SWR meter alone ***basic*** circuit is simple construction, too, is simple ***if*** the unit is designed for limited range of frequencies circuit does not operate at resonance; in a matched condition, therefore, voltage extremes are avoided when used with an unbalanced transmission line (no balun), efficiency of power transfer is limited primarily by the Q of the inductor; with a quality inductor, efficiency can approach 100%	simplicity of construction becomes lost if the unit must cover broad f or Z ranges because extremely high or low values of L and C become necessary on 160m, for example, a low-pass L network requires approximately 6,000 pF of C to match a 4-ohm resistive load, approximately 7,000 pF to match a 3-ohm resistive load, and approximately 8,700 pF to match a 2-ohm resistive load; even a 25-ohm resistive load (representing a mere 2:1 SWR) requires approximately 1,770 pF of C the C values stated in the preceding paragraph are merely for purposes of illustration and comparison – typical 160m antennas are shorter (often much shorter) than resonant length; such antennas tend to be not only low in impedance but also very high in capacitive reactance, and are not primarily resistive	Ten-Tec 238B Unique Products Company (UPC) Unique Wire Tuner UPC Unique Wide Range Wire Tuner [this later model also can be fed in an L network high-pass configuration, see L network – high pass, below] Collins 180S-1 [this unit also can be configured as a pi network, see Pi network – low pass, below]	1. Simplified Design of Impedance-Matching Networks, Grammer (W1DF), *QST* (Mar.; Apr.; May 1957) 2. *Reflections Transmission Lines and Antennas*, Maxwell (W2DU) (1990), Chapter 14 3. *The ARRL Antenna Book* (20th ed., 2003), Chapter 25 4. Experiment #21: The L-Network, Silver (NØAX), *QST* (Oct. 2004) 5. A Graphical Look at the L Network, Pattison (N6RP), *QST* (Mar. 1979) 6. Matching-Network Design, Dorbuck (K1FM), *QST* (Mar. 1979)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – low pass (continued from previous page)	amenable to auto-tuner applications, especially with step switched, rather than continuously variable, circuit values – but, during the switching interval, an infinite SWR can be presented to the source, thus exposing the output devices in the source to damage or destruction if any SWR-protection circuitry in the source cannot respond quickly enough to the transient condition modest attenuation of harmonics relative to other matching circuits, it is easy in an L network to calculate the voltages and currents that the components will see at a given power level; thus, it is relatively easy to determine the needed ratings for the components	on 10m, on the other hand, such a network requires L values below 1 micro-Henry (often *well* below 1 micro-Henry) for resistive loads all the way from 2 ohms through 500 ohms (many roller inductors have too high a minimum L, especially when augmented by stray L in the circuit, to accommodate this requirement; it should be noted, too, that even a high quality roller inductor is apt to suffer from relatively low Q at the bottom end of its inductance range); for a 2,000-ohm resistive load, moreover, such a network requires only 17 pF of C, a value that might well be exceeded by the minimum C of an ordinary variable capacitor, especially when augmented by stray capacitance introduced by the wiring and component arrangement in the circuit, not to mention proximity to enclosure panels the C and L values stated above should be compared to those for a high-pass L network [see Disadvantages (and Other Considerations) under L network – high pass, below]		7. How to Evaluate Your Antenna Tuner – Part 2, Witt (AI1H), *QST* (May 1995) (see also Notes 8 and 10, below)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – low pass (continued from previous page)		on the basis of the circuit values stated above, it becomes apparent that with typical commercially available (and affordable) components, it is difficult with a low-pass L network to attain enough C to match low impedance loads on 80 and, especially, on 160m; it is difficult, moreover, to achieve adequately low values of L with a high-L inductor or adequately low values of C with a high-C capacitor as a result, a design intended to cover an f range that encompasses 160m through 10m, or extremes of load impedance (especially impedances with a high ratio of X to R), requires either or both of (i) elaborate arrangements for switching among components to achieve a wide range of L and C values, and (ii) substantial performance compromises at and near the limits of the tuners range such elaboration, moreover, tends to introduce enough stray L and C actually to undermine the circuits overall matching range		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – low pass (continued from previous page)		an ordinary, non-elaborated L-network design, therefore, has a matching range that is significantly narrower than what can be achieved with more complex circuits, such as those described elsewhere in this table matching is difficult at or near 1:1 SWR no dc isolation between transmitter and load loaded Q is not constant over a range of load impedances; the Q varies with the square root of the transformation ratio; causing QSY bandwidth to vary with transformation ratio unsuitable for use with balanced transmission lines without a broadband balun inserted on the output side of the tuner network (see companion article Baluns in Matching Units on the CD-ROM that accompanies the *Antenna Book*) on the other hand, an L network, because of its simplicity and efficiency, is particularly appropriate for use with antennas on 160m, especially with low-Z loads		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – low pass (continued from previous page)		on that band, the pragmatic consequences of the inability of a tuner to operate with balanced transmission line in the absence of a broadband balun are reduced because (i) owing to physical scale, balanced antennas are not apt to be either feasible or efficient; and (ii) the low-mismatch-loss attributes of balanced transmission line are less beneficial than at higher frequencies		
L network – high pass (series C, shunt L)	exhibits dc isolation between transmitter and load	little attenuation of harmonics requires even more C and L than a low-pass L network, slightly more C and L at high SWR, and drastically more at low SWR on 160m, for example, a high-pass L network requires approximately 6,500 pF of C to match a 4-ohm resistive load, approximately 7,400 pF to match a 3-ohm resistive load, and approximately 9,000 pF to match a 2-ohm resistive load; but even a 25-ohm resistive load (representing a mere 2:1 SWR) requires over 3,500 pF of C, double the value required in a low-pass L network	UPC Unique Wide Range Wire Tuner [this model also can be fed in an L network low-pass configuration, see L network – low pass, above]	

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
L network – high pass (series C, shunt L) (continued from previous page)		on 10m, on the other hand, where sufficiently low values of C and L can be difficult to attain, the requirement of additional C and L might well prove to be an advantage the C and L values stated above should be compared to those for a low-pass L network [see Disadvantages (and Other Considerations) under L network – low pass, above] (in other respects, too, see L network – low pass, above)		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Balanced L network – low pass	although balanced, this configuration nevertheless depends upon a broadband balun for use with balanced transmission line; the balun, however, can be placed on the input side of the network, where transformation ratios and voltages tend to be lower than on the output side, and where stresses on the balun therefore are likely to be lower; this is said to give the balanced L design a decided advantage over a conventional unbalanced L, where a balun must be inserted on the output side of the tuner network if a balanced transmission line is to be used; in this regard, it should be noted that analyses by Schmidt and others (see Note 10) demonstrate that, in the context of an ***unbalanced*** configuration, placing the balun on the input side confers no advantage (in other respects, see L network – low pass, above)	requires a broadband balun on the input side of the tuner network (see companion article Baluns in Matching Units on the CD-ROM that accompanies the *Antenna Book*) requires matched and ganged roller inductors which, especially in a high-power unit, add to the expense and complexity of construction; this also compounds the difficulty and complexity of constructing a unit that will provide efficient coverage of an extended range of f and Z (in other respects, see L network – low pass, above)	Bliss Match Master Palstar AT1500BAL Palstar BT1500A	8. A *Balanced* Balanced Antenna Tuner, Measures (AG6K), *QST* (Feb. 1990) 9. A Balanced, Everyday Approach to All-Band Bliss, Kleinschmidt (NTØZ), *QST* (April 2002) 10. Putting a Balun and a Tuner Together, Schmidt (W9CF), http://fermi.la.asu.edu/w9cf/
Pi network – low pass (series L, shunt C)	considerable attenuation of harmonics within limits, circuit operating Q can be chosen (where the load resistance substantially exceeds the impedance that the source wants to see, Q is approximately equal to the load resistance divided by the capacitive reactance of the output capacitor	circuit is more complex than an L network, requiring two variable capacitors	Nye-Viking MB-V-A	(see Notes 1, 2, 3, 6, and 7, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Pi network – low pass (series L, shunt C) (continued from previous page)	of the network) can achieve large impedance-transformation ratios with a lower value of L than that needed in an L network or a high-pass T network; smaller values of L tend to lead to lower losses in the inductor	circuit operates at resonance, so suffers from possibly large voltage rise at resonance; this requires capacitors (at least the one on the high-impedance side of the network) to have a higher voltage rating than is needed for the single capacitor in an L network more difficult to tune than an L network, because three variable components must be managed more than one combination of variables will produce a match (if L is variable), but matched condition alone does not assure maximum efficiency of power transfer; it becomes important, therefore, to measure not only SWR but also E or I in the transmission line no dc isolation between transmitter and load unsuitable for use with balanced transmission lines without a broadband balun on the output side (see companion article Baluns in Matching Units on the CD-ROM that accompanies the *Antenna Book*)	Drake MN-2000 Drake MN-2700 [in addition to the pi components, these Drake units have additional variable capacitance in series with the load on the output side of the network] Collins 180S-1 [this unit also can be configured as a low-pass L network, see L network – low pass, above]	

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Pi network – low pass (continued from previous page)		with variations specific to its circuit architecture, the pi network shares a disadvantage in common with the L network, that is, a design intended to cover an f range that encompasses 160m through 10m, or extremes of load impedance (especially impedances with a high ratio of X to R), requires either or both of (i) elaborate arrangements for switching among components to achieve an adequate range of L or C values; and (ii) substantial performance compromises at and near the limits of the tuner's range indeed, the pi network requires values of C that can be substantially greater than that needed for the single capacitor in an L network		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
T network – high pass (series C, shunt L)	can achieve large impedance-transformation ratios with lower values of L and C than those needed in an L network, and lower values of C than those needed in a pi network with low-Z loads on 80m and 160m, however, the price in increased circuit losses of this advantage becomes rather high; with inadequate values of C, a high-pass T network might indeed achieve a match, but it can be a ruinously inefficient one at 1.83 MHz, for example, with a 4-ohm resistive load and an inductor with a Q of 100 (which is not always easy to achieve with a roller inductor), efficiency may be predicted (by comparing the parallel equivalent resistance of the inductor with the impedance at that point in the circuit) to be only 62% if C1 and C2 are limited to 500 pF each; at the same f, Z, and inductor Q, C1 needs to be approximately 6,260 pF and C2 needs to be approximately 6,030 pF to achieve a predicted efficiency of 96%; these latter values of C turn out to be quite similar to the C needed in a low-pass L network but *two* of such capacitors are needed in the T network (see Note 11 and L network – low pass, above,)	circuit is more complex than an L network, requiring two variable capacitors more difficult to tune than an L network, because three variable components must be managed little attenuation of harmonics unsuitable for use with balanced transmission lines without a broadband balun on the output side (see companion article Baluns in Matching Units on the CD-ROM that accompanies the *Antenna Book*) with variations specific to its circuit architecture, the T network shares a disadvantage in common with the L network, that is, a design intended to cover an f range that encompasses 160m through 10m, or extremes of load impedance, requires either or both of (i) elaborate arrangements for switching among components to achieve an adequate range of L or C values, and (ii) substantial performance compromises at and near the limits of the tuner's range	Ameritron ATR-30 Dentron MT-3000A Dentron AT-3K Heath SA-2060 Heath SA-2500 N4XM Xmatch Vectronics HFT-1500	11. Estimating T-network losses at 80 and 160 meters, Schmidt (W9CF), *QEX* (July 1997) (see also Notes 1, 2, 3, 6, and 7, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
T network – high pass (continued from previous page)	exhibits dc isolation between transmitter and load	The majority of tuners manufactured for the ham market in the T network – high pass configuration are remarkably inefficient on 160m, especially with low-Z loads; although these tuners might be capable of producing a nearly perfect match, they do so at an L/C ratio that is far too high for efficient operation because these tuners tend to have far too little C to accommodate a desirable L/C ratio (see the text under Advantages for this circuit) with variations specific to its circuit architecture, the T network shares a disadvantage in common with the L network, that is, a design intended to cover an f range that encompasses 160m through 10m, or extremes of load impedance, requires either or both of (i) elaborate arrangements for switching among components to achieve an adequate range of L or C values, and (ii) substantial performance compromises at and near the limits of the tuner's range indeed, the majority of tuners manufactured for the ham market in the T network – high pass configuration are remarkably inefficient on 160m, especially with low-Z loads; although these tuners might be capable of producing a perfect (or nearly perfect) match, they do so at an L/C ratio that is far too high		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
T network – high pass (continued from previous page)		for efficient operation; this is because these tuners tend to have far too little C to accommodate a desirable L/C ratio (see the text under Advantages for this type of circuit) a few low-pass T network tuners manufactured for the ham market are claimed to have adequate C for efficient operation with low-Z loads on 160m; such claims, however, seem suspect; such units, moreover, tend to be poor performers on 10m because their minimum C is too high to permit a desirable L/C ratio on that band		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Differential T network – high pass (series C, shunt L)	adjustment is simplified, relative to a conventional T network, because a single controls varies both the input C and the output C; this offers convenience to the operator, and can constitute a significant advantage in possible auto-tune applications relative to a conventional T network, the differential T is far less susceptible to gross mis-tuning; this tends to afford a safety factor against the consequences of hasty or careless adjustment (in other respects, see T network – high pass, above)	because the input C and the output C cannot be controlled independently of each other, settings that achieve a match are unlikely also to achieve the highest efficiency of power transfer; the linkage of the capacitors also somewhat reduces the matching range thus, a differential T can be expected to produce higher losses than a properly adjusted conventional high-pass T network; the magnitude of the increased losses, however, is greatest with low-SWR loads, and diminishes into insignificance with high-SWR loads (in other respects, see T network – high pass, above)	MFJ-986	(see Note 11, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Balanced T network – high pass	although balanced, this configuration nevertheless depends upon a broadband balun for use with balanced transmission line; the balun, however, can be placed on the input side of the network, where transformation ratios and voltages tend to be lower than on the output side, and where stresses on the balun therefore are likely to be lower; this is said to give the balanced T design a decided advantage over a conventional unbalanced T, where a balun must be inserted on the output side of the tuner network if a balanced transmission line is to be used; in this regard, it should be noted that analyses by Schmidt and others (see Note 10) demonstrate that, in the context of an ***unbalanced*** configuration, placing the balun on the input side confers no advantage (in other respects, see T network – high pass, above)	requires matched and ganged variable capacitors, both on the input and the output sides; especially in a high-power unit, these capacitors add to the expense and complexity of construction; this also compounds the difficulty and complexity of constructing a unit that will provide efficient coverage of an extended range of f and Z (in other respects, see T network – high pass, above)	MFJ-974H MFJ-976	

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Balanced T network – low pass	considerable attenuation of harmonics (in other respects, see Balanced T network – high pass, above)	requires matched, tapped, and switched inductors, both on the input and the output sides; especially in a high-power unit, these inductors and their associated switches add to the expense and complexity of construction; this also compounds the difficulty and complexity of constructing a unit that will provide efficient coverage of an extended range of f and Z (in other respects, see T network – high pass, above)		12. GR-1500 Unbalanced-to-Balanced Transmatch, O'Dell (KB1N), *The ARRL Handbook for the Radio Amateur* (63rd ed., 1986), Chapter 34

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***without*** variable C in series with primary winding)	especially suited to balanced transmission lines because the secondary circuit has an inherently balanced configuration; as a result, no broadband balun is needed easy to tune because, for a given load and frequency, only one combination of settings of the capacitors will produce a match; as a result, the need for metering of transmission-line current or voltage is obviated, and tuner adjustment can be achieved with an SWR meter alone considerable attenuation of harmonics exhibits dc isolation between transmitter and load	matched condition does not necessarily coincide with maximum efficiency of power transfer in this circuit configuration, there is no direct method to tune the primary circuit to resonance; as a result, it becomes necessary to couple capacitive reactance into the primary from the secondary circuit so as to cancel the reactance of the primary inductor and, thereby, to permit the source to see a purely resistive load; consequently, the secondary must be tuned to resonance at a frequency somewhat different from the operating frequency, thereby causing the secondary to exhibit a net reactance at the operating frequency, and thus causing the needed capacitive reactance to be coupled into the primary (see parenthetical discussion below); this departure from resonance in the secondary should have the fringe benefit of avoiding some of the voltage rise that occurs in resonant circuits (continued on following page)	Johnson Matchbox	13. five-part treatise by Cebik (W4RNL) www.cebik.com (as updated on 11-28-1997): Part I: Inductive Coupling Part II: The Input Story Part III: The Output Story Part IV: Series Circuits and Reactance Part V: Components, Construction, and Measurement 14. Link-Coupled Antenna Tuners, Cebik (W4RNL) www.cebik.com (as updated through 08-04-2006) 15. Match Box Tuner, Marriner (W6BLZ), *73* (Sept. 1966) (continued on following page)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***without*** variable C in series with primary winding) (continued from previous page)		(a parallel circuit becomes inductive below its resonant frequency because, in the equation X = (-XL x XC)/(XL-XC), XC exceeds XL below resonance, thereby causing the denominator to go negative and X thus to go positive, i.e., inductive; according to Cebik – see Note 13 – this inductive reactance becomes reflected into the primary as capacitive reactance because the coupling process inverts the sign of the reactance; Cebik concludes, therefore, that – to achieve a match – the secondary must be tuned to a frequency higher than the operating frequency; it appears, however, that Cebik's proposition is valid only in very limited circumstances; it appears that, in general, net reactance in the secondary couples reactance of the same sign, rather than of the opposite sign, into the primary; it appears, therefore, that – to achieve a match in most situations – the secondary must be tuned to a frequency lower than the operating frequency) (continued on following page)		16. *The A.R.R.L. Antenna Book* (9th ed., 1960), Chapter 3 17. Build a Dual-Differential Capacitor for Your Antenna-Tuning Network, Boyer (W9ZSI), *QST* (Oct. 1972) 18. Homemade Differential Capacitors, Pavlowski (W3QPU), *QST* (Nov. 1977) 19. Differential Capacitor Ideas, Berger (W7HPI), in Hinks and Kinks, *QST* (Jun. 1978) 20. Differential Capacitor Ideas, Barnard (W6ST), in Hinks and Kinks, *QST* (Jun. 1978) (see also Note 7, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***without*** variable C in series with primary winding) (continued from previous page)		the absence of variable C in series with the primary somewhat constricts the matching range of the unit construction is complicated by the need for an inductor with closely coupled primary and secondary windings, and with multiple, symmetrical taps on the secondary; standard, manufactured coils are not ideal for this service; as a result, the best results are apt to be achieved only with the effort of custom building the coil if a reasonably compact package is desired, construction is further complicated by the need for a dual differential capacitor for the capacitive voltage divider on the output; such a capacitor either is a non-standard, expensive item to purchase, or is a somewhat difficult item to build on a custom basis (continued on following page)		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***without*** variable C in series with primary winding) (continued from previous page)		Maxwell (see Note 2), however, concludes (i) that the shunt portions of Johnson's dual-differential output capacitor contribute nothing to the matching process; and (ii) that, accordingly, ganged, single-section capacitors, one in series with each leg of the transmission line, would perform just as well as the Johnson arrangement; query, however, whether the approach suggested by Maxwell would preserve circuit balance to the degree achieved by the Johnson design it would seem, moreover, that Maxwell's analysis ignores the distinction between a differential capacitor, on the one hand, and an ordinary split-stator capacitor, on the other (continued on following page)		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***without*** variable C in series with primary winding) (continued from previous page)		when the Johnson output capacitor is adjusted so that each of the two series arms has maximum – or near maximum – capacitance (and, therefore, relatively low capacitive reactance), each of the two shunt arms will have minimum – or near minimum – capacitance (and, therefore, enough reactance to be nearly an open circuit); in this situation, each shunt arm would carry negligible current, omitting them therefore would not affect the match, and Maxwell would be correct in contrast, when the Johnson output capacitor is adjusted so that each series arm has minimum – or near minimum – capacitance (and, therefore, relatively high capacitive reactance), each shunt arm will have maximum – or near maximum – capacitance (and, therefore, relatively low reactance); in this situation, each shunt arm would carry significant current, omitting them therefore would affect the match quite substantially, and Maxwell would be decidedly incorrect		

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Inductively coupled – with capacitive voltage-divider output (variation ***with*** variable C in series with primary winding)	a match can be selected, from a range of possible matches, that should offer maximum efficiency of power transfer because of the variable C in series with the primary, this configuration has the potential to cover a somewhat wider matching range than can be covered by the Johnson Matchbox design (in other respects, see Inductively coupled – with capacitive voltage-divider output – variation ***without*** variable C in series with primary winding, above)	variability of C in series with primary winding means that a match can be achieved under a variety of control settings, of differing respective efficiencies; this makes for complicated tuning and renders it necessary to measure not only SWR but also transmission-line E or I to determine maximum power transfer (in other respects, see Inductively coupled – with capacitive voltage-divider output – variation ***without*** variable C in series with primary winding, above)	Annecke Symmetrischer-Kurzwellen-Antennen-Koppler	21. A Wide-Range Coupler for Any Antenna, McCoy (W1ICP), *The Radio Amateur's Handbook* (39th ed., 1962), Chapter 13 (see also Notes 13, 14, and 16, above)
Inductively coupled – with tapped-inductor output (variation ***with*** variable C in series with primary winding)	(see Inductively coupled – with capacitive voltage-divider output – variation ***with*** variable C in series with primary winding, above)	(see Inductively coupled – with capacitive voltage-divider output – variation ***with*** variable C in series with primary winding, above)		22. A Link-Coupled Matching Network, *The Radio Amateur's Handbook* (61st ed., 1984), Chapter 19 (see also Notes 13, 14, and 16, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
ARRL tuner (N6BV design) (variation on T network – high pass) In this variation, the network is floated above chassis ground and the balun is placed on the input side	(see T network – high pass, above)	(see T network – high pass, above)	MFJ-9982 [This unit varies slightly from the ARRL tuner. Unlike the N6BV design, the MFJ unit features fixed C in shunt with the input to the T network. As a result, the MFJ unit bears a similarity to the Ultimate Transmatch circuit although, in the latter design, the shunt C is variable.] Palstar AT4K Palstar AT5K	23. High-Power ARRL Antenna Tuner for Balanced or Unbalanced Lines, Straw (N6BV), *The ARRL Antenna Book* (20th ed., 2003), Chapter 25 (see also Note 11, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
SPC tuner (W1FB design) (variation on T network – high pass) In this variation, an additional variable capacitor is placed in parallel with the inductor	considerably greater suppression of harmonics than a standard high-pass T network (in other respects, see also T network – high pass, above)	can be expected to suffer greater losses than a standard high-pass T network, ranging from a 50% greater loss at an SWR of 1 to double the loss at low load resistances (in other respects, see T network – high pass, above)		24. A Transmatch for Balanced or Unbalanced Lines, *The Radio Amateur's Handbook* (61st ed., 1984), Chapter 19 25. Ultimate Transmatch Improved, DeMaw (W1FB), in Technical Correspondence, *QST* (July 1980) 26. The Ultimate vs. the SPC Transmatch, Maxwell (W2DU), in Technical Correspondence, *QST* (Aug. 1981) (see also Note 11, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Ultimate Transmatch (W1ICP design) (variation on T network – high pass) In this variation, the source is fed into the rotor of a split stator capacitor, with one stator providing input series C and the other input shunt C	(see T network – high pass, above)	significantly less effective than a standard high-pass T network on lower frequencies because the split-stator input capacitor (in comparison to a single-section capacitor of equal total C) produces at its maximum (i) a reduced value of C in its series arm; and (ii) such little C in its shunt arm (and, therefore, such high reactance on 80m and, especially, on 160m) as to be virtually an open might also produce somewhat greater loss than a standard high-pass T network (see Note 26) (in other respects, see T network – high pass, above)	Heath SA-2040 [This unit varies in one detail from the Ultimate Transmatch circuit. In the Heath design, the split-stator input capacitor is a differential capacitor. Thus, the input capacitor serves as a capacitive voltage divider, electronically tapping the roller inductor.] Murch UT-2000 James Millen 92200 [The manufacturer's literature for this unit states that it is a band-switched L network. (continued on following page)	27. The 50-Ohmer Transmatch, McCoy (W1ICP), *QST* (July 1961) 28. The Ultimate Transmatch, McCoy (W1ICP), *QST* (July 1970) (see also Notes 11, 25, and 26, above) [The article referred to in Note 28 is essentially a rehash of the article referred to in Note 27. The innovations in the later design consist merely of replacing the band-switched inductor with a roller inductor, and adding a balun on the output for use with balanced transmission lines.]

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Ultimate Transmatch (W1ICP design) (continued from previous page)			While the unit does ***include*** a band-switched L network, an examination of the circuit diagram reveals the overall configuration of the unit to be, in fact, a high-pass T network of the Ultimate Transmatch variety. Indeed, the product literature specifically acknowledges the unit to be a commercial version of the 1961 W1ICP design, a direct precursor of the Ultimate Transmatch.]	

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Z Match (variation on Inductively coupled – ***with*** variable C in series with the primary winding) This variation is a switch-free multi-band design that simultaneously feeds two transmission lines, each to its own, separate antenna. In the classic version, there are two pairs of inductively coupled coils having their respective primaries connected to each other in parallel.	simultaneously covers two broad ranges of frequencies (nominally 3:1), each encompassing two or more HF bands (classically 80 & 40m and 20-15-10m), thus obviating the need to switch or vary the inductances	because of the 3:1 limit to the f ranges of each of the two arms of this circuit, it appears that the design cannot be made to cover the entire 160m - 10m range efficiently, at least in the absence of circuit elaboration	Harvey-Wells Electronics, Inc. Bandmaster Z Match Antenna Coupler	(see Note 16, above)

Type of Circuit	Advantages	Disadvantages (and Other Considerations)	Commercial Examples	Reference Notes
Z Match (continued from previous page) One coil pair has a higher-inductance primary and secondary, with the secondary feeding its own transmission line to an antenna for 3.5 and 7 MHz. The other coil pair has a lower-inductance primary and secondary, with the secondary feeding its own transmission line to an antenna for 14, 21, and 28 MHz.				

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