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J. ALTMAYER

3,513,472

IMPEDANCE MATCHING DEVICE AND METHOD OF TUNING SAME

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FIG. 2

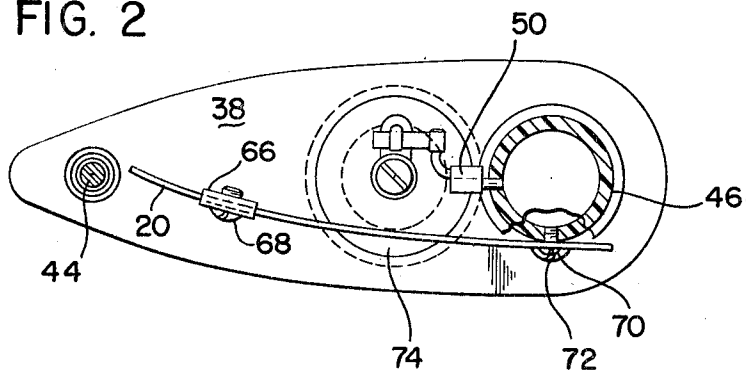


FIG. 3

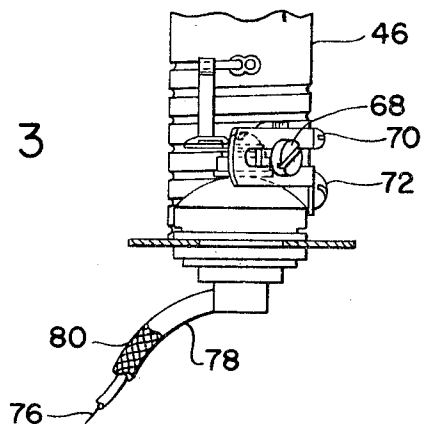


FIG. 1

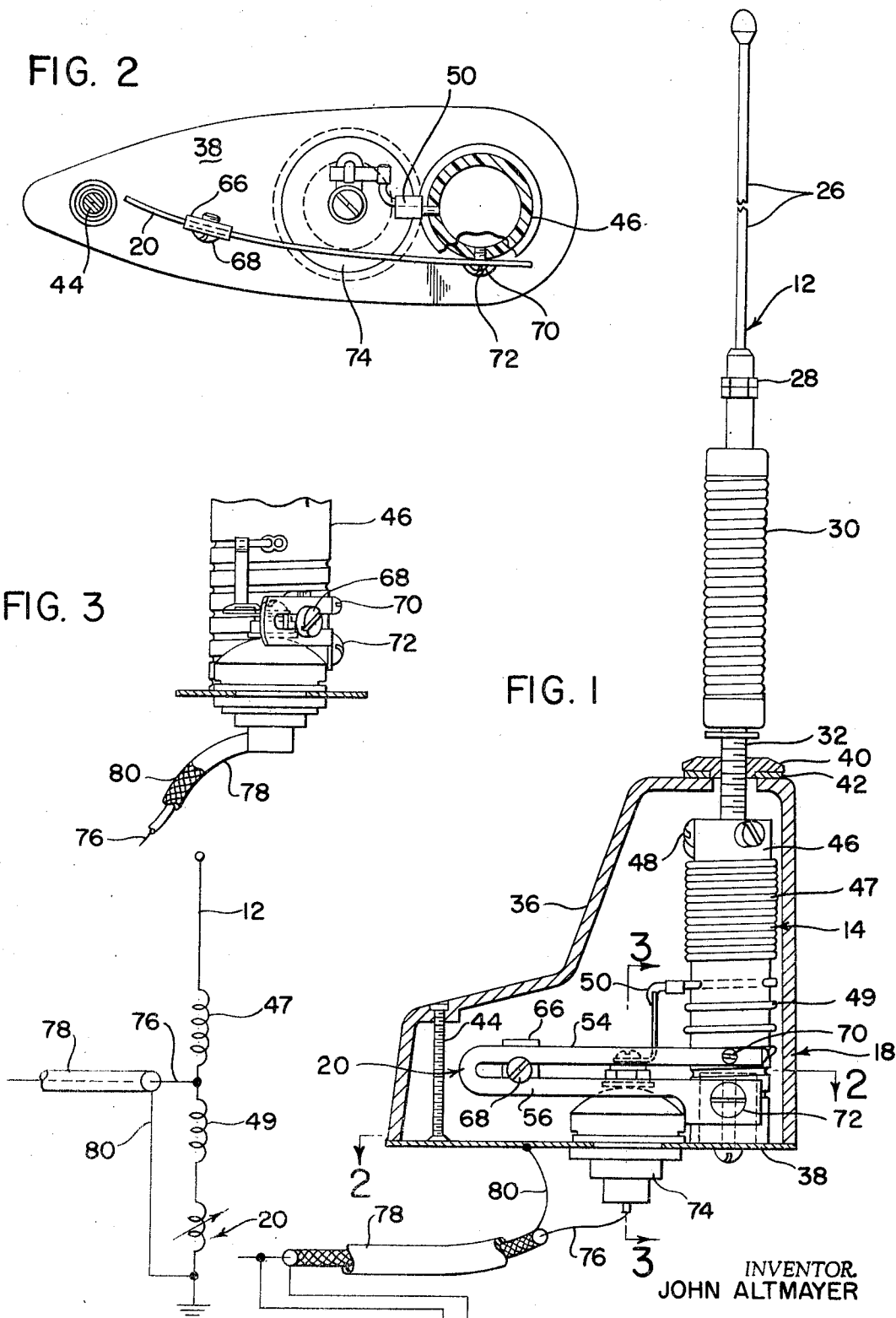


FIG. 4

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IMPEDANCE MATCHING DEVICE AND METHOD OF TUNING SAME

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6 Claims

ABSTRACT OF THE DISCLOSURE

An antenna having a vertical whip, a base loading coil, and an impedance matching stub connected between a lower terminal of the loading coil and a ground terminal. The stub includes a pair of close-spaced, generally parallel, conductive members and an adjustable shorting strap connected to and extending between the pair of conductive members for altering the input impedance of the antenna.

This invention pertains to the art of radio antennas and more particularly to coil-loaded antennas having adjustment means for matching the input impedance of the antenna to the characteristic impedance of a coaxial cable transmission line.

The invention is particularly applicable to base-loaded, roof-mounted, vertical, mobile antennas of the type fed with a coaxial cable transmission line and used in business communications, and will be described with particular reference thereto; however, it will be appreciated that the invention has broader applications and may be used in various applications which require an accurate matching of the input impedance of the antenna to the characteristic impedance of the transmission line.

Base-loaded antennas known heretofore normally include a vertical whip, and a base loading coil having an upper terminal connected to the bottom of the vertical whip and a lower terminal connected to the center conductor of a coaxial cable. The outer shield of this cable is connected to a ground terminal. This arrangement often results in a very high mismatch between the input impedance of the antenna and the characteristic impedance of the coaxial cable, thereby causing a high standing-wave ratio and a substantial loss of transmitted power.

It has also been conventional to connect the lower terminal of the base loading coil to the ground terminal, and to connect the center conductor of the coaxial cable to a tap on one of the turns of the loading coil to provide a more accurate match between the input impedance of the antenna and the characteristic impedance of the coaxial cable. With this arrangement, in order to alter the input impedance of the antenna, it was necessary to unsolder the tap, move this tap to a new point on the coil, and resolder the tap to the coil at this new point. Since the adjustment of the tap must be very precise and accurate, it was often necessary to move this tap many times prior to final adjustment. This problem might be partially overcome by providing an adjustable tap; however due to the relatively poor electrical contact made by the adjustable tap with the coil, an increased resistance was introduced into the antenna system, and frequently only intermittent contact was made by the tap with the turns of the coil.

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The present invention is directed toward a new and improved antenna which overcomes all of the above referred-to difficulties and others, and provides an impedance matching device which is simple in construction, effective in operation and which can be simply tuned by the installer.

In accordance with the present invention, an antenna is provided which includes a vertical whip, and a base loading coil having one terminal connected to the whip, and the other terminal connected to an impedance matching stub. The impedance matching stub is comprised of a pair of close-spaced, generally parallel conductive members, one of which is connected to the base loading coil and the other is connected to a ground terminal, and an adjustable shorting strap connected to and extending between the pair of conductive members whereby the input impedance of the antenna may be accurately altered.

In accordance with a more limited aspect of the present invention, the pair of conductive members takes the form of a thin, U-shaped, conductive member having an adjustable shorting strap extending between the legs of the U-shaped member for varying the impedance of the coil, thereby altering the input impedance of the antenna.

In accordance with another aspect of the present invention, there is provided a method of matching the input impedance of a base-loaded antenna to the characteristic impedance of a coaxial cable transmission line, which comprises placing a fixed input tap on a base loading coil at a point which is as close to the optimum point as possible and then adjusting a shorting bar extending between two parallel members to obtain a precise impedance match between the antenna and the coaxial cable.

The primary object of the present invention is to provide an antenna having an adjustable means for accurately matching the input impedance of an antenna to the characteristic impedance of a coaxial cable transmission line.

Another object of the present invention is to provide a base-loaded, vertical antenna having a tap permanently located on one of the turns of the coil, wherein the input impedance of the antenna may be simply and accurately altered.

Another object of the present invention is to provide an impedance matching arrangement which eliminates the necessity of physically moving a tap from one turn of the coil to another turn of the coil.

In accordance with a still further object of the present invention, there is provided a base-loaded, vertical antenna which is fed with a coaxial cable transmission line, in which the feed-point impedance of the antenna may be matched with extreme accuracy to the characteristic impedance of the coaxial cable transmission line.

Another object of the present invention is to provide an impedance matching arrangement which is simple in design and is of rugged construction.

A still further object of the present invention is to provide a method of accurately matching the input impedance of an antenna to the characteristic impedance of a coaxial-cable transmission line.

These and other objects and advantages of the invention will become apparent from the foregoing description of the preferred embodiment of the invention as read in connection with the accompanying drawing in which:

FIG. 1 is an elevational view of the antenna construction in accordance with the preferred embodiment of the

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present invention with portions of the protective cover broken away;

FIG. 2 is a cross-sectional view taken generally along line 2—2 of FIG. 1;

FIG. 3 is an elevational view taken generally along line 3—3 of FIG. 1; and

FIG. 4 is a schematic circuit diagram of the antenna of FIG. 1.

Referring now to the drawings wherein the showings are for purposes of illustrating a preferred embodiment of the invention and not for purposes of limiting same, FIG. 1 illustrates an adjustable, vertical, radiating element 12, loading coil 14, housing 18, and an adjustable impedance matching stub 20 for altering the feed-point impedance of the antenna.

The vertical radiating element 12 includes a vertical whip 26, adjustable chuck 28, spring 30, and threaded shaft 32, which are of conventional design and constructed of conductive material, such as stainless steel, although other suitable materials are contemplated as within the scope of the invention. The adjustable chuck 28, is comprised of a split-sleeve and clutch-nut assembly to thereby provide a means for adjusting the overall length of the vertical radiating element 12.

Housing 18 includes an outer shell 36, which is of conventional design and is constructed of a dielectric material, such as fiberglass, and a conductive base plate 38. The nut 40 and washer 42, in combination with the screw 44, serve to secure the outer shell 36 to the base plate 38, and prevent the entrance of moisture into the housing 18.

Loading coil 14 is mounted on a cylindrical, dielectric coil form 46, and is comprised of an upper coil section 47 having one terminal connected to a screw 48, and having the other terminal connected to one terminal of a lower coil section 49. Screw 48 is threaded into the coil form 46 and provides an electrical connection between loading coil 14 and shaft 32, which is threaded into the end of the coil form 46. Situated at the connection point between the upper coil section 47 and the lower coil section 49 is a fixed tap 50 which provides an input terminal for the antenna. As illustrated in FIG. 1, the lower coil section 49 is comprised of coil turns which are spaced from each other to decrease the sensitivity of the impedance matching arrangement.

Stub 20 is comprised of a conductive U-shaped member having a pair of legs 54, 56 which extend in a common plane and are substantially parallel to each other. The stub 20, is preferably very thin in form, as is shown in FIG. 2, and may be formed by conventional stamping processes. Extending between the legs 54, 56 of stub 20 is a conductive, L-shaped, adjustable shorting strap 66, in which one leg of the strap rests on the upper edge of leg 54, and the other leg is in contact with the flattened portions of the pair of legs 54, 56. The strap 66 is secured to stub 20 by a screw 68. Thus, shorting strap 66 may be moved to any desired position along the stub 20, and may be retained at that point by tightening screw 68. As can be seen in FIGS. 1 and 2, the adjustable shorting stub 20 is mounted on the coil form 46 adjacent to the lower coil section 49, and is retained in position by screws 70, 72 of which the latter provides an electrical connection between leg 56 and the base plate 38. Leg 54 of the stub 20 is connected to the lower coil portion 49.

The tap or input terminal 50 extends through a feed-through insulator 74 and is connected to the center conductor 76 of the coaxial cable 78. Connected to the base plate 38, which provides a common ground point for the antenna, is the outer shield 80 of the coaxial cable 78.

The preferred embodiment of the antenna system of the present invention, as shown in FIG. 1, is of the type which is generally mounted on a portion of an automobile body such as the roof. In this environment, the outer

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conductor 80 of the coaxial cable 78 is also connected directly to the body of the car, wherein the body of the car acts as a ground plane when the antenna is operated at a relatively higher frequency, and appears as a capacitance to ground when the antenna is operated at a lower frequency.

Referring now to FIG. 4, there is illustrated a schematic circuit diagram of the antenna in which the elements corresponding to those in FIGS. 1—3 are accordingly similarly numbered. The vertical radiating element 12 is connected to one terminal of the upper coil section 47, and the other terminal of coil section 47 is connected to the center conductor 76 of the coaxial cable 78, and to one terminal of the lower coil section 49. The other terminal of lower coil section 49 is connected to one terminal of the variable inductance or adjustable shorting stub 20, and the other terminal of stub 20 and the outer shield 80 of the coaxial cable 78 are connected to a common ground point.

It will be observed from FIG. 4, that the input impedance to the antenna is that impedance measured between the center conductor 76 of the coaxial cable 78 and the ground point. Further, it will be noted that as the variable inductance or adjustable shorting stub 20 is varied, the input impedance to the antenna will be accordingly altered.

OPERATION

In the operation of the antenna of the present invention, as with most antennas, highest radiation efficiency is obtained when the antenna is tuned to resonate at a desired frequency of operation. Further, the maximum operating efficiency is obtained when the transfer of power between the transmission line and the antenna is greatest, and this occurs only when the input impedance of the antenna is properly matched to the characteristic impedance of the transmission line or coaxial cable 78.

In order to resonate the antenna, it is necessary that the inductive reactance of the antenna be made equal to the capacitive reactance of the antenna, so that the input impedance to the antenna appears to be purely resistive. Generally, if the radiating section of the antenna is of a length equal to one-quarter wavelength, one-half wavelength or a multiple wavelength of the operating frequency, the above-indicated reactances will be substantially equal at the operating frequency, and the antenna will be substantially resonant. In the event the antenna is to be mounted on an automobile, or employed in portable operation, an antenna having a length of a quarter-wavelength of the operating frequency may be impracticable, particularly on the relatively lower frequency bands. As the length of the antenna is decreased from that of a quarter-wavelength of the operating frequency, the input impedance of the antenna will appear to be an increasingly large capacitive reactance, thereby decreasing the radiation efficiency of the antenna system. To compensate for this capacitive reactance for an antenna having a length less than a quarter-wavelength, it is necessary to tune out this capacitive reactance by the addition of a lumped inductance in series with the antenna, which may take the form of the upper coil section 47 in combination with the lower coil section 49, and the adjustable shorting stub 20.

As indicated above, the highest radiation efficiency occurs when the maximum power applied to the transmission line or coaxial cable 78 is transferred to the antenna. The characteristic impedance of a transmission line is generally of a constant value, for example the characteristic impedance of the commonly used coaxial cables, RG-8/U and RG-58/U, are on the order of 50–55 ohms. However, when a base-loaded, vertical antenna is fed at the base with a resonant radio frequency signal, the radiation resistance at that feed-point will be a very low impedance i.e. on the order of 5 or 6 ohms. Since the characteristic impedance of the commonly used trans-

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mission lines is much higher than this value, a substantial mismatch will result. When such a mismatch occurs between the input impedance to the antenna and the characteristic impedance of the transmission line, the standing-wave ratio will be greater than unity, and will result in a substantial loss of transmitted power.

As indicated above, the input impedance at the base of a base-loaded, vertical antenna is of a very low value; however, as the feed-point is moved away from the base of the antenna, the input impedance increases in value. Referring to FIG. 4, the addition of the lower coil section 49 and the adjustable shorting stub 20, have the general effect of moving the feed-point to a position on the vertical element remote from the base, thereby increasing the input impedance to the antenna. The adjustable shorting stub 20 provides a means of adjusting the impedance of these elements to thereby accurately, and very precisely, match the impedance of the antenna to the characteristic impedance of the coaxial cable 78.

TUNING THE ANTENNA

In manufacturing the antenna of the present invention, the number of turns of coil 14 are chosen to provide an antenna which is as close to resonate at the operating frequency as is possible. Similarly, the tap 50 is situated at a point on the coil 14 which is as close to the optimum point as is possible; however, since no two vehicles have the same electrical characteristics, such as the capacitance between the body of the vehicle and ground, the antenna of the present invention includes fine adjustment means to compensate for these different electrical characteristics. In order to resonate the antenna, both as to resonance at the desired frequency of operation, and as to the proper impedance matching between the transmission line and the antenna, a S.W.R. meter S is connected across the conductors 76, 80 of the coaxial cable 78. A small radio frequency excitation signal of the desired frequency is then applied to the coaxial cable 78, the adjustable chuck 28 is loosened slightly, and the vertical whip 26 is adjusted to provide a minimum S.W.R. indication. The adjustable shorting strap 66 is then moved along the adjustable shorting stub 20 to obtain a minimum indication on the S.W.R. meter. Since the adjustable shorting strap 20 is an effective part of the entire inductive reactance of the antenna, the adjustment of shorting strap 20 will affect, to a small degree, the resonant frequency of the antenna. In order to compensate for this minor change in the resonant frequency of the antenna, it is necessary to again adjust the length of the vertical whip 26 to obtain a minimum S.W.R. indication. The adjustable chuck 28 and screw 68 are tightened to retain the vertical whip 26 and the shorting strap 66 in the desired position.

While the preferred embodiment of the invention illustrates the impedance matching device with a base-fed, base-loaded, roof-mounted, vertical, mobile antenna, it will be appreciated that this matching arrangement may be employed with various other antenna systems. The invention has been described in connection with a particular preferred embodiment, but is not to be limited to the same. Various modifications may be made without departing from the scope and spirit of the present invention as defined by the appended claims.

Having thus described my invention, I claim:

1. An antenna having an input impedance and comprising a vertical radiating element, a ground terminal, a loading coil having a first and a second terminal, said first terminal being connected to said radiating element, and a tap connected to said coil at a point on said coil between said first and said second terminal, the improvement comprising a pair of conductive members extending in a common plane and being substantially parallel to each other; one of said pair of conductive members being connected to said second terminal of said loading coil, and the other of said pair of conductive members being connected to said ground terminal;

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a shorting strap extending between said pair of conductive members; said shorting strap being adapted to be moved along said conductive members to thereby alter said input impedance of said antenna to match a given characteristic impedance of a transmission line; and

means for retaining said shorting strap at a given position along said pair of conductive members.

2. An antenna as defined in claim 1 wherein each of said pair of conductive members is an elongated conductive member; and said shorting strap is mounted on and adjustably secured to at least one of said members so that said strap may be moved along said members to thereby alter the input impedance of the antenna.

3. An antenna as defined in claim 1 wherein the improvement comprises a first and a second conductive member forming the legs of a generally U-shaped configuration;

said first conductive member being connected to said second terminal of said loading coil and said second conductive member being connected to said ground terminal;

an adjustable means connected to and extending between said first and said second conductive members to thereby alter the input impedance of the antenna; and,

a means for retaining said adjustable means at a given position on said first and second conductive members.

4. An antenna as defined in claim 3 wherein said adjustable means is a conductive plate being orientated in superimposed parallel relationship with a plane defined by said first and said second conductive members; said plate extending between said first and said second conductive member and being adjustably secured to at least one of said conductive members so that said plate may be moved along said conductive members to thereby alter the input impedance of the antenna.

5. An antenna system as defined in claim 4 including a dielectric coil form having a first and a second end and an outer cylindrical surface; said vertical radiating element being threadably secured into said first end of said coil form; said loading coil being mounted on said outer cylindrical surface of said coil form and extending along said outer surface generally from said first end to a given point along said coil form; said first conductive member and said second conductive member being secured to the outer cylindrical surface of said coil form generally at said given point and at said second end of the coil form, respectively.

6. A method of accurately matching the input impedance of an antenna to the characteristic impedance of an antenna to the characteristic impedance of a transmission line; said transmission line having a first and a second conductor, comprising the steps of:

(a) providing a vertical radiating element; a base loading coil being connected to said radiating element; a first and second conductive member extending in a common plane and being substantially parallel to each other, said first conductive member being connected to said loading coil and said second conductive member being connected to said first conductor of said transmission line; and an adjustable shorting strap extending between said first and said second conductive member;

(b) connecting said second conductor of said transmission line to said loading coil at a point on said coil which is approximately an optimum point to match the antenna to the transmission line;

(c) connecting a standing-wave ratio meter across said first and second conductor of said transmission line;

(d) applying a radio frequency signal of a given frequency to said conductors of said transmission line;

(e) adjusting the length of said radiating element until said standing-wave ratio is at a minimum indication

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thereby substantially resonating the antenna to the given frequency;

(f) sliding said shorting strap along said first and second conductive member until a point is reached at which said standing-wave ratio is at a minimum indication thereby matching the impedance of the antenna to the characteristic impedance of the transmission line;

(g) securing said shorting strap at said point;

(h) adjusting the length of said radiating element until said standing-wave ratio is at a minimum indication thereby again resonating the antenna to the given frequency; and

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(i) securing said radiating element to said first and second conductive member.

References Cited

UNITED STATES PATENTS

2,941,204	6/1960	Bailey	-----	343—861
3,453,618	7/1969	Ukmar et al.	-----	343—749

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U.S. Cl. X.R.

333—33; 343—861, 900