NEW TOOLS TO CO-LOCATE WIRELESS FACILITIES WITH AM ANTENNAS

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Abstract - *Wireless telecommunication providers continue to improve their transmitting equipment. This industry has seen the move to tower-mounted transmitters and receivers (known as Remote Radio Units). This has made obsolete the use of long lengths of coaxial cable for the wireless industry thus improving the system performance and providing substantial cost savings. These RRUs are fed with two fiber optic connections and a pair of 6 AWG wires for 48 VDC power. Typical wireless configurations have multiple RRUs for varying bands (700 MHz, 800 MHz, 1900 MHz and 2100 MHz) with configurations having up to 16 RRUs per cell site. Many AM stations have had wireless facilities co-locate on their towers to provide additional revenue. When placing these wireless facilities on series fed medium wave antenna systems some additional considerations must be made to manage the transition across the base insulator. With careful engineering these facilities are quite compatible. Kintronic Labs and others have historically offered products such as isolation coils and iso-couplers to help these services transition the base region of the AM antenna. A new isolation coil design has been introduced that makes use of aluminum jacketed multi conductor hybrid cable for RRU installations. This paper will discuss the application of this technology for installation of wireless facilities on AM stations.*

Introduction

Many of the Medium Wave (MW)[1] transmitting facilities world wide have been approached by wireless operators with requests to co-locate mobile telephone base station antennas on MW antenna towers. As the density of wireless facilities increases and the process of obtaining local building permits for towers becomes more challenging, more MW towers have become desirable locations for wireless facilities.

Often wireless companies are under the mistaken impression that they cannot co-locate with MW stations.

In MW antenna systems, the vast majority of facilities are base insulated towers (Figure 1) that use the steel in the tower as the energized portion of the antenna. These towers are electrically isolated from ground. This is not the case for FM, TV, Land Mobile, and Wireless systems which operate at much higher frequencies (VHF & UHF).[2] These services use antennas that are attached to the tower structure. MW towers typically have as much as several thousand volts from the tower base to ground but can support other antennas and aviation obstruction lighting fixtures as long as the isolation between the systems is carefully engineered. Wireless facilities make good tenants and can provide a nice revenue stream for the radio station. A typical base driven, insulated AM tower is not difficult to use for mounting other antennas, and indeed may already have isolation for sample loops and tower lighting installed [2].

Fig 1 Typical Base Insulator, Antalya, Turkey

[1] Medium Wave (MW) - 300 kHz to 3 MHz encompass the AM Broadcast Band 550 kHz to 1700 kHz where the wavelength varies from 545 meter (1788 feet) to 176 meters (578 feet) - lower frequencies have longer wavelengths

[2] VHF - Very High Frequency 30 MHz to 300 MHz and UHF - Ultra High Frequency 300 MHz to 3 GHz

Definition of Problem

Isolating the wireless facility from the MW antenna correctly is important for the operation of the MW station and the wireless facility. For the MW station, additional equipment on the tower can cause the antenna bandwidth to be degraded and can significantly change the operating impedance of the antenna system. If the wireless equipment is not isolated, it will ground the tower and the MW station will not be able to operate. If the wireless equipment is isolated poorly, the MW station can have its tuning severely thrown off , its bandwidth degraded, or both. Poorly isolating the wireless equipment can also produce dangerous radio frequency voltages in inappropriate locations, endangering personnel and destroying the wireless equipment.

Traditional Solutions to the Problem

Isolating Lighting Circuits

AC electrical circuits used to feed aviation obstruction lighting on MW towers have typically been isolated using one of two methods. These are isolation transformers (trade name Austin Ring Transformers) and lighting chokes. Isolation transformers for this application use toroidal wound configurations that have the primary winding separated from the secondary winding where the primary is at ground level and the secondary is mounted on the energized tower (Figure 2, 3, and 4). The primary and secondary are looped together [3].

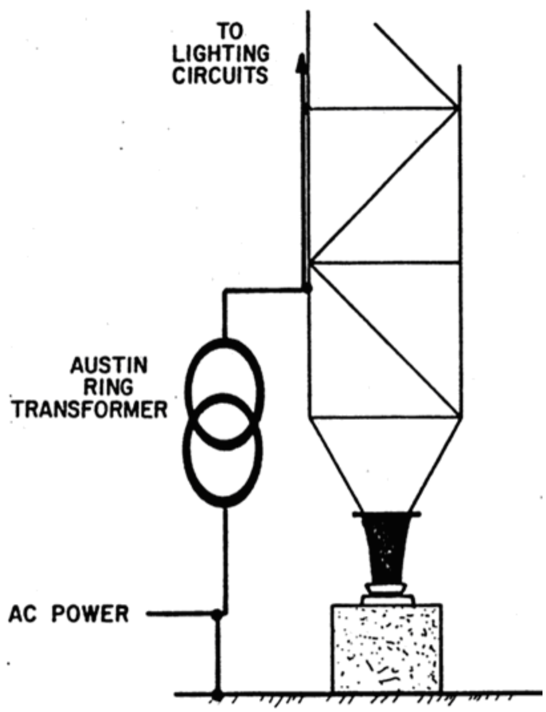

Fig 2 Austin Transformer Schematic

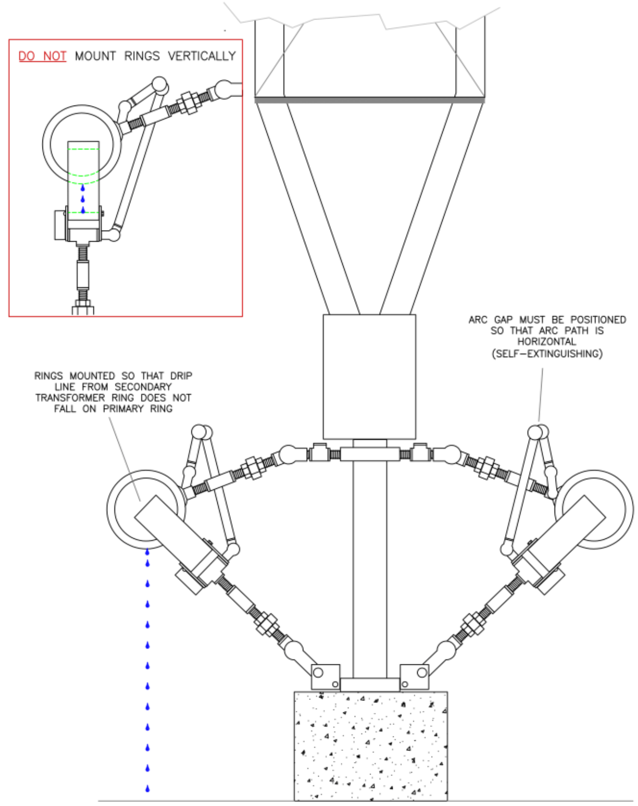

Fig 3 Austin Transformer Installation

Fig 4 Typical Properly Installed Austin Transformer, Mersin, Turkey

The second and more common method is the lighting choke (coil or inductor) which has the electrical wires wound cylindrically, forming a tightly spaced solenoid, to provide a high impedance at the MW station's operating frequency. Bypass capacitors are then used to prevent the AC voltage from passing onto the tower or onto RF ground and to minimized the RF energy coupled into the AC system (Figure 5 and 6). This allows the AC to cross the base insulator and isolates the MW station from the electrical system. These are manufactured in various configurations of number of conductors, size of conductors, and design for high voltage RF. These can be used for AC and DC electrical circuits [4].

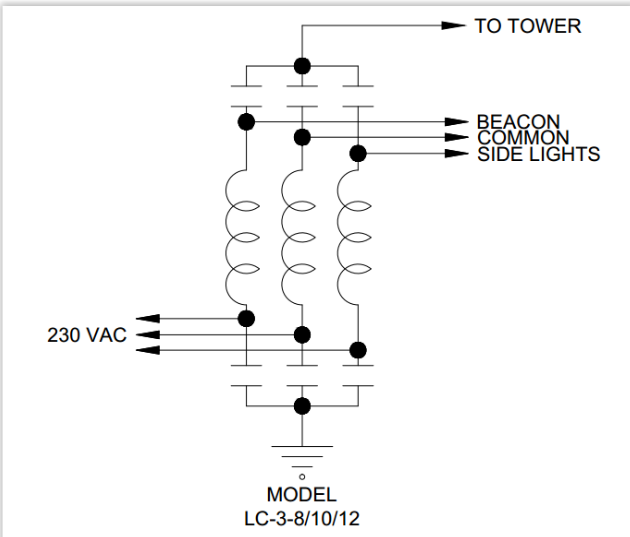

Fig 5 Standard 3-Wire Lighting Choke Schematic

Fig 6 Lighting Choke Example with 6 Conductors Isolated

Isolating Radio Frequency Devices with Isolation Inductors (Iso-Coils)

RF devices such as land mobile antennas or sample systems can transit the base insulator by the use of isolation coils (iso-coils). These are constructed by cylindrically winding a coil using coaxial cable with either a solid metal outer jacket or a substantial braided outer shield (Figure 7, 8, and 9). The coaxial cable provides a pathway to the antenna that is mounted on the tower, yet provides a high impedance across the MW tower base [4][5].

Iso-coils are sometimes parallel resonated with a variable capacitor - particularly on high impedance towers. They can also be tapped for impedance control. When the bandwidth capabilities of other transformer devices such as iso-couplers are not sufficient, these iso-coils can be used, so long as the losses in the length of necessary coaxial cable can be tolerated. Iso-coils can even be wound with elliptical waveguide for microwave applications.

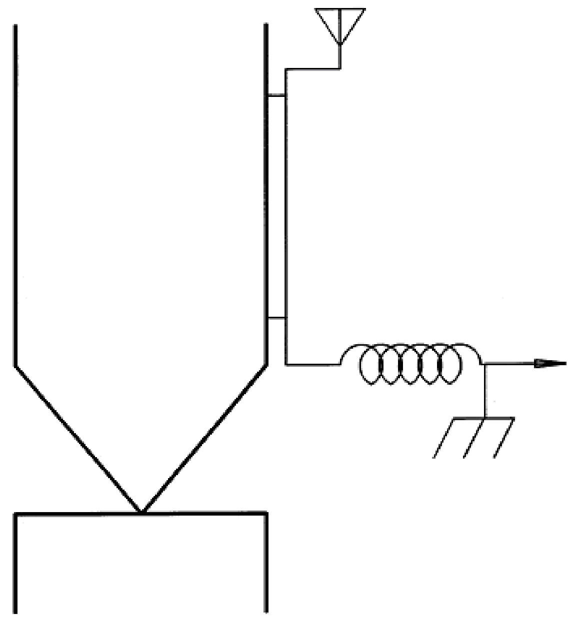

Fig 7 Isolation Coil Schematic

Fig 8 Isolation Coil for MediaFLO TV Facility at WJR

Large iso-coils can have sufficient inter-winding capacitance to present an impedance that is inductive at the low end of the band (380 μH +j1290 Ohms) and capacitive at the high end of the band (63.5 pF -j1475 Ohms) as shown in Fig 9 (a high impedance at right side of Smith Chart). The transition point can be tuned by a variable tap on the coil.

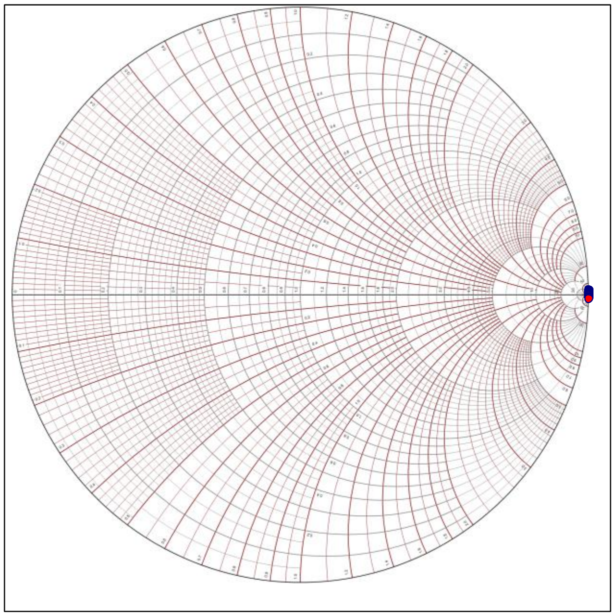

Fig 9 Smith Chart Plot of Iso-Coil for MediaFLO TV Facility at WJR

Fig 10 Iso-Coils for Wireless Facility Isolating
12 Separate 7/8" Coaxial Lines

Iso-coils can also be made using slotted copper pipe to allow a variety of individual conductors and cables to be encased in the pipe for passage onto the MW tower. Figure 11 shows an example in which several lighting circuit conductors and a 1/2" coaxial line are passed through a slotted iso-coil. Figures 12 and 13 show a more extreme example in which a large copper pipe is slotted and used to pass 21 separate conductors and a 1/2" coaxial line. Bundled along with the slotted copper pipe are three unjacketed 7/8" coaxial lines, all of which are bundled together to form a single, large-diameter conductor that forms the winding of this large iso-coil. This example makes use of a parallel resonating vacuum variable capacitor to greatly mitigate the effects of this large iso-coil on the tower base impedance.

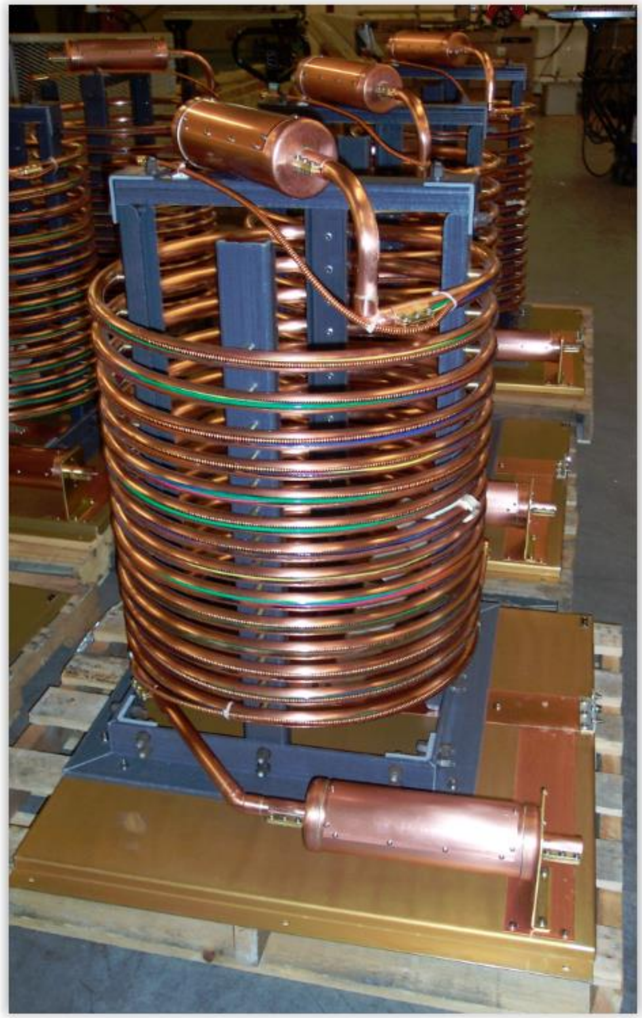

Fig 11 Slotted Iso-coil Example

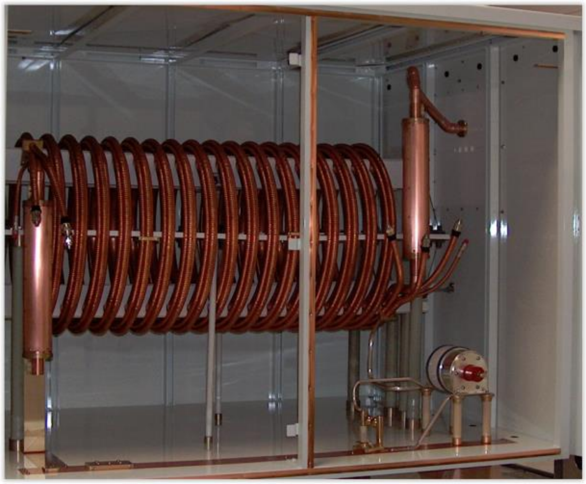

Fig 12 Large Slotted Iso-coil Example

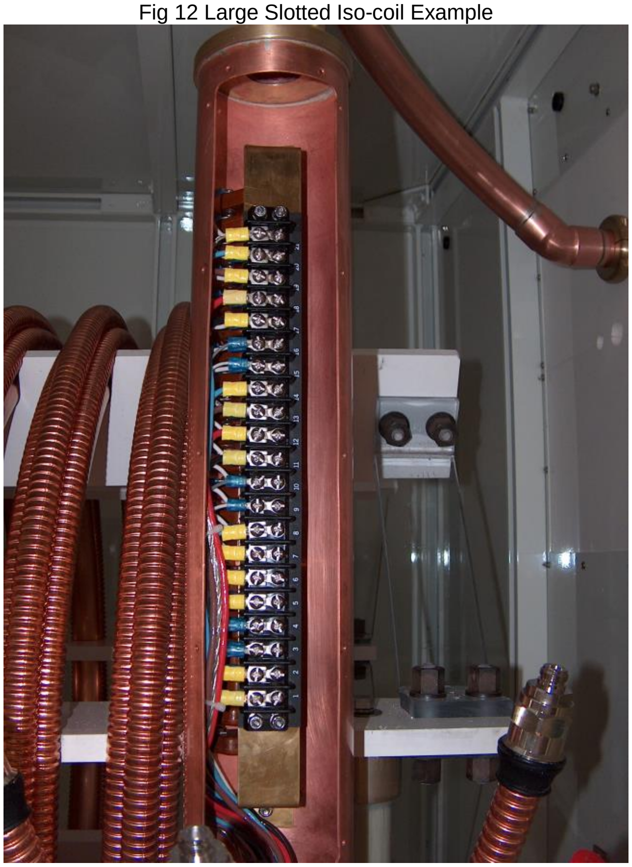

Fig 13 Large Slotted Iso-Coil Terminal Box
for Multiple Conductors

Iso-coils can also be wound using any cable with a suitable conductive outer shield, such as multi-conductor control and monitoring cables, Cat5 cables, etc. Figures 14 and 15 give an example in which a multi-conductor RET (remote electrical tilt) control cable was made into an iso-coil and used along with a group of lighting chokes to provide 12 separate #10 AWG power conductors. This was installed on a 2-tower array with no difficulties [7].

Fig 14 Remote Electrical Tilt (RET) Cable Iso-Coil

Fig 15 Multiple Lighting Chokes Provide DC Power

Isolating Radio Frequency Devices with Iso-Couplers

RF devices also can transit the MW antenna base using devices that use transformer coupling. These have been called iso-couplers (Figure 16). These devices place two loops in close proximity and pass the signal across the tower base. Isolation for the MW station is achieved by an air gap between the loops. These devices are narrowband and are tuned for the pass frequency of the RF devices, yet provide a high impedance across the base [3].

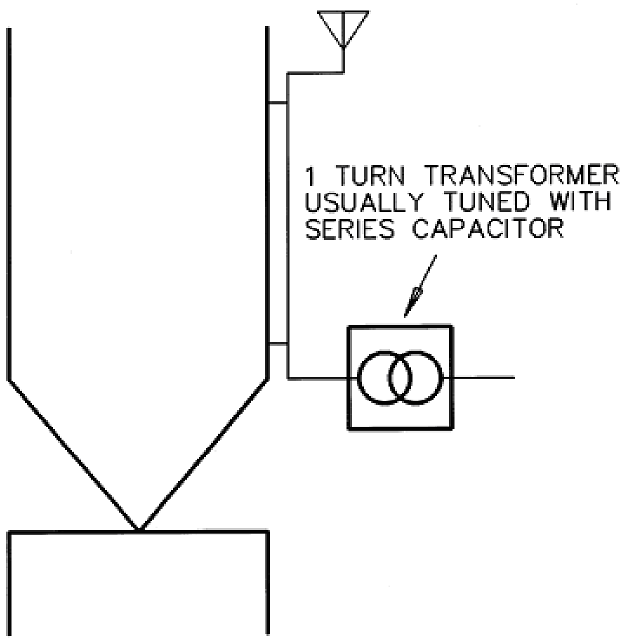

Figure 16 Iso-Coupler Schematic

Fig 17 Typical Iso-Couplers for a Wireless Facility

The challenge with wireless installations has been the number of antennas required for a single cellular base station. These systems typically use two antennas per sector with three sectors at each site. This represents at least six isolation devices for a simple installation. Increasingly more base stations are adding additional frequency bands and it is not unusual to have sites with three bands with three sectors, which could add up to eighteen unique signal paths. (Figure 17)

The wireless industry has also been trying to minimize the amount of coaxial cable as it represents a large expense and provides a significant structural issue with many towers due to wind loading. The past few years have seen the industry move to tower-mounted transmitters and receivers (known as Remote Radio Units). These RRUs are fed with two fiber optic connectors and a pair of 6 AWG wires for 48 VDC power (Figure 18). Wireless system designers have insisted on feeding each RRU with separate 48 VDC connections. They do this so they can be rebooted remotely and individually. Typical wireless configurations have multiple RRUs for varying bands (700 MHz, 800 MHz, 1900 MHz, and 2100 MHz) with configurations up to 16 RRUs per cell site. For the standard wireless site, this has a great advantage. However, this is a challenge when installing these systems on MW antennas systems. The fiber optic cables are non-conductive, and as long as they are appropriately physically supported, they can transit the base insulator with no deleterious effects on the MW station.

When faced with the problem of installing one of these systems on a MW facility, we noted that Radio Frequency System (RFS) was manufacturing a cable assembly that provided the 6 AWG wires [6], 18 AWG alarm wires, and fiber optic strands all in an aluminum corrugated armor jacket. These hybrid cables come in various configurations of numbers of pairs and diameters, and can be ordered with connectors factory installed on the fiber as well. An example is shown in Figure 18.

Fig 18 Hybrid Cables Providing Power, Alarm, and Fiber

After some discussion, we determined that this cable can be wound into an iso-coil (Figure 19). This would keep the MW station's antenna load unperturbed and provide a good isolated path across the base insulator for the wireless equipment. Since the fibers already had factory connectors, the cable would not be cut into in order to insert the iso-coil. Instead, the full length needed to travel from the shelter to the tower base, to wind the iso-coil, and to ascend the tower to the RRUs would be used. The iso-coil was wound in the mid-section of the cable run. The excess length to reach the shelter and to ascend the tower was stowed in spools atop the unit for shipping. The unit was also tuned to resonance with a vacuum variable capacitor, as shown in Figure 19.

Fig 19 Iso-Coil Using Hybrid Cable

Conclusion

We believe that isolation coils made from a wide variety of cables, including those constructed from hybrid cable, will be a useful solution for the co-location of wireless facilities on MW broadcast towers. This will allow beneficial revenue for the broadcaster and allow for lower costs for the wireless providers. These isolation systems can be custom designed and manufactured and many are standard off-the-shelf components [8].

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[6]http://www.rfsworld.com/userfiles/press_releases/hybriflex/rfs-sellsheet-hybriflex-april_2010-2.pdf

[7] System installed by Phil Harris of Sitesafe

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